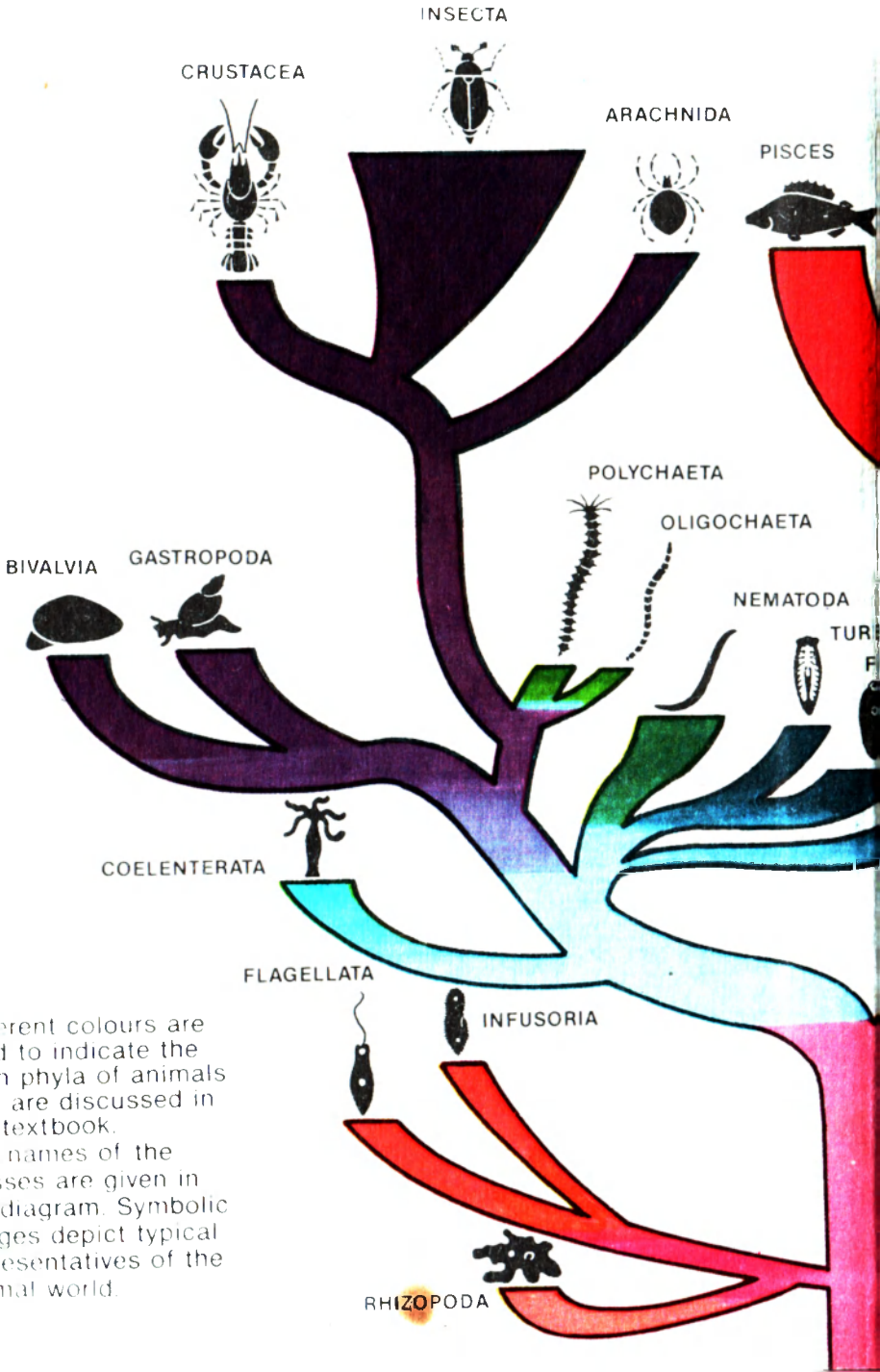
ZOOLOGY

TEXTBOOK FOR SCHOOLS

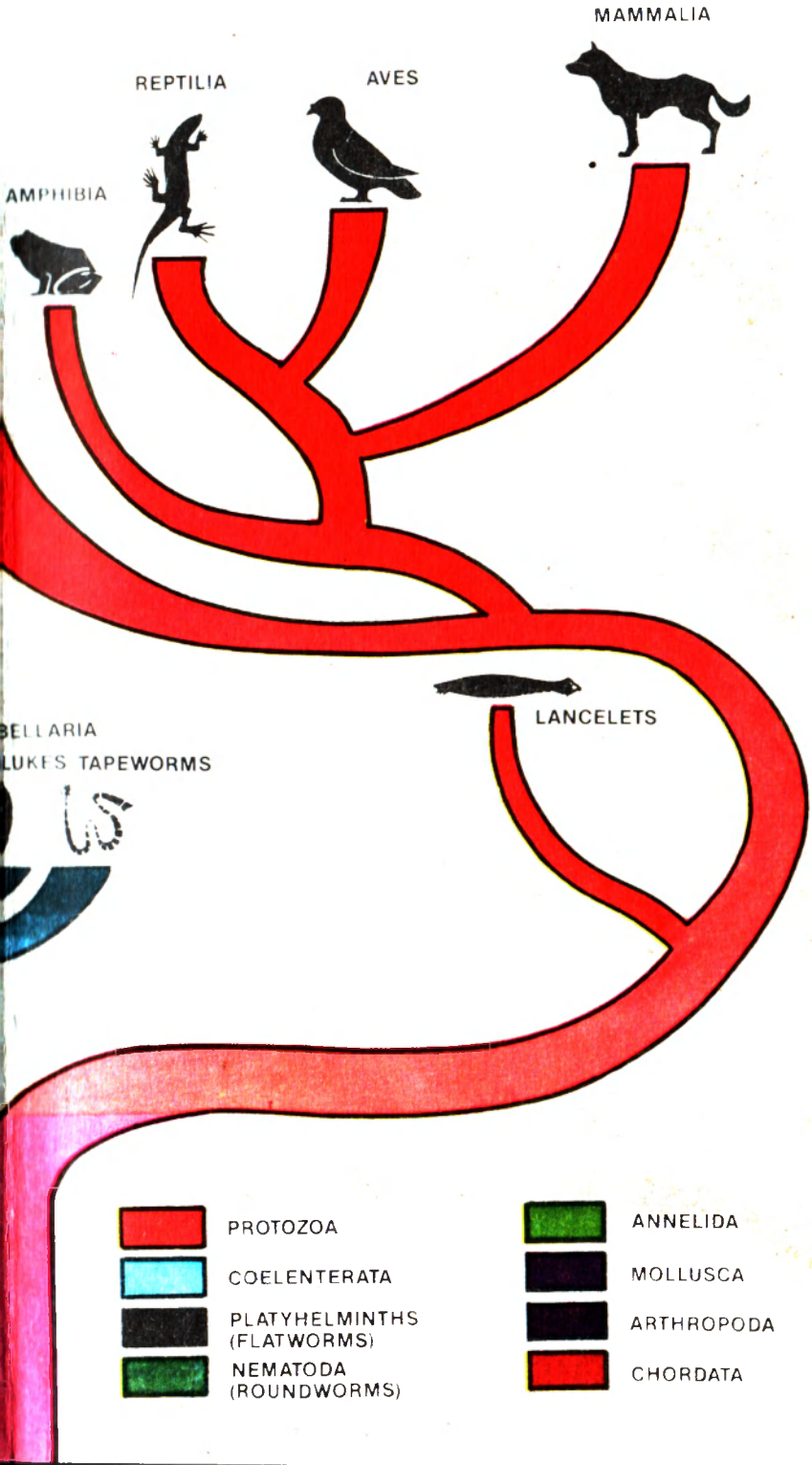
Edited by
D. Naumov

Mir Publishers Moscow

DIAGRAM OF ANIMAL WORLD EVOLUTION



Different colours are used to indicate the main phyla of animals that are discussed in the textbook. The names of the classes are given in the diagram. Symbolic images depict typical representatives of the animal world.


MAMMALIA
REPTILIA
AVES
AMPHIBIA
LANCELETS
PROTOZOA
COELENTERATA
PLATYHELMINTHS
(FLATWORMS)
NEMATODA
(ROUNDWORMS)
ANNELIDA
MOLLUSCA
ARTHROPODA
CHORDATA

ZOOLOGY Textbook for Schools

Mir Publishers Moscow

ЗООЛОГИЯ

Под редакцией
профессора Д. В. Наумова

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ZOOLOGY

TEXTBOOK FOR SCHOOLS

Edited by D. Naumov

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M. Rosenberg

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T. A. Ginetsinskaya, D. Sc. (Biol.)
and Cynthia Martin

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B. E. Bykhovsky, E. V. Kozlova, A. S. Monchadsky, D. V. Naumov,
A. S. Sokolov, N. A. Rykov, P. V. Terentyev

HOW TO USE THE TEXTBOOK

First get acquainted with the contents of the textbook. Some words in the text are printed *in italics* to make it easier to remember zoological terms. If the species of an animal is followed by an exclamation mark (!), it means that this animal is rare and should be protected. On the margins of the book next to the questions and assignments you will see a red question mark (?), or a red triangle Δ, which means that the questions and assignments are given for review in order to remember the material better. If the assignment is marked by a red square ■, it should be accomplished by observing living animals, making experiments with them, or studying the structure of dissected animals.

Examine carefully the insides of the front and back covers of the textbook, where you will find reference data on zoology. An appendix is given at the end of the textbook, containing brief characteristics of the main phyla and classes of animals, as well as symbolic images of representatives of various classes. You will find the same images on the inside front cover, illustrating schematically the evolutionary trends of the main groups of the animal world. The index of main zoological terms indicates the pages where the terms are used.

На английском языке

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Introduction

Zoology–the Science of Animals

THE ANIMAL WORLD AND ITS SIGNIFICANCE IN NATURE. Animals inhabit the whole world: the land surface, soil, freshwaters and seas. When climbing up the Chomolungma (Mount Everest), mountaineers found mountain birds, choughs, at an altitude of about 8000 m. Worms, crustacea, mollusks, and other animals have been discovered in the deepest depressions of the world ocean down to a depth of 11 000 m. We don't notice many types of animals in our everyday life because of their concealed mode of life, or due to their microscopic sizes. On the contrary, we encounter other types of animals continuously, for example, insects, birds, beasts.

The significance of animals in nature is just as great as the significance of plants. When studying botany, you learned that many plants are pollinated only by animals, that animals play an important role in disseminating seeds of some plants. It is necessary to add that animals, along with bacteria, participate actively in soil formation. Earthworms, ants, and other small animals continuously introduce organic matter into the soil and crush it, thereby contributing to the formation of humus. Water and air penetrate into the soil and reach plant roots more easily through the holes of burrowing animals. You know from botany that green plants enrich the air with oxygen, which is necessary for the respiration of all living beings. Plants serve as food for plant-eating animals, and, in turn, the latter are the food of predators. Thus, animals are unable to exist without plants. But, as stated above, the life of plants depends on the vital activity of animals.

The sanitary significance of animals is very great because they eliminate dead bodies of other animals, remains of dead plants, and fallen leaves. Many aquatic animals purify water, the purity of which is just as important for life as the purity of air.

SIGNIFICANCE OF ANIMALS FOR MAN. The animal world was always of great significance for man. Our remote ancestors, who lived 100 000-150 000 years ago, knew wild beasts, birds, fishes, and other animals. This is quite clear because the life of people depended greatly on hunting and fishing. The meat of animals was one of the major sources of food, the hides were used for making clothes, the bones–for making knives, scrapers, needles, spear heads. The tendons were used instead of thread for sewing the hides and for bow-strings. The success of hunting depended not only on the strength and adroitness of the hunters, but on the skill of finding a bird's nest or a beast's lair, finding the necessary tracks, determining the correct time for a battue. Certain animals were caught in snares and nets, others by lying in ambush,

still others had to be pursued with loud noise by the whole tribe and driven into camouflaged pits. It was important for man to escape predators, distinguish venomous snakes from harmless ones.

Having learned the habits of wild beasts, people of ancient times managed to domesticate some of them. The dog was the first domestic animal. It was used to help in hunting. Pigs, cattle, poultry were domesticated some time later.

The role of animals in the life of man changed over the course of time. The significance of wild beasts as a source of food reduced greatly, because meat, wool, and milk were produced by domestic animals. But new enemies of man appeared in the animal world: various insects, who were pests of cultivated crops. History knows many cases when whole nations suffered from hunger owing to the destruction of the harvest by hordes of locusts.

Many wild animals found themselves under strenuous living conditions in the 20th century owing to the vast scope of man's economic activities: felling of forests, construction of hydraulic power plants, expansion of cultivated areas, etc. The number of wild animals reduced, some of the species became rare, others disappeared entirely. Sometimes rapacious hunting contributed to the extermination of valuable animals. It became necessary to protect them.

It is known that animals play a very important part in providing the Earth's population with food and raw materials for industry. Man receives a substantial amount of food stuffs, as well as leather, wax, silk, wool, and other raw materials from domestic animals. Fishing, especially marine fishing, the gathering of crustacea and mollusks are also important in the production of food, vitamins, medicinal preparations, etc., and the wastes are used for making feed meal that is used for fattening cattle and producing fertilizers. The fur of wild animals is used for trimming and sewing clothes. Other parts of animal body are used in industry (leather, horns, shells, etc.). Many animals (for example, birds and predatory insects) play an important role in exterminating pests of cultivated and valuable wild plants.

It is known that many animals cause harm to the human economy. Among them are pests of cultivated crops, animals who exterminate reserves of food, damage articles of leather, wool, wood, etc. There are animals that cause various diseases (malaria, helminthic diseases, scabies, etc.). Some animals are disease carriers (lice carry epidemic typhus from sick people to healthy ones, mosquitoes transmit malaria, fleas – the plague).

The animal world is a significant component of the environment. Caring for it is the basis for its reasonable utilization. Knowing the specific features of individual species and their role in nature, man can protect useful animals, help to increase their populations, restrict the reproduction of agricultural pests, carriers of diseases and pathogenes. Protection of the animal world is a national concern in our country.

STUDYING THE ANIMAL WORLD. Only a comprehensive study of the animal world enables us to estimate correctly the role of each species of animals in nature and its significance for man.

Zoology is a science dealing with animals, their diversity, structure, behaviour, reproduction, development, origin, dissemination, and interrelationship with the environment, and their significance in nature and human life. The term *zoology* comes from two Greek words: *zoon* – animal, and *logos* – word, teaching, science.

Animals, like plants that you have studied earlier, are living organisms. Therefore, they have much in common. Both are formed by complex organic substances: proteins, fats, carbohydrates, etc. Both have a cellular structure, and many similar vital processes. All this points to the relationship of plants and animals and to their origin from a common ancestor. When studying zoology, you will learn of some animals who are very close to plants.

At the same time, there are great differences between plants and animals. Green plants can create organic matter of their bodies from inorganic substances in the environment by means of photosynthesis. Animals (with very rare exceptions) are incapable of photosynthesis and build their bodies using the organic matter of plants or other animals. Unlike plants, the majority of animals are capable of locomotion and can make various movements.

The animal world populating our planet is quite diverse. The number of plant species reaches about 500 000, while animals number approximately 1 500 000 species. Scientific taxonomy of animals resembles the taxonomy of plants. As in the case of plants, all animals of one species are similar in structure. This similarity is not accidental: it depends on their close relationship, on their origin from a common ancestor. Animals of one species lead a similar mode of life and occur in nature on a certain territory. They can crossbreed and produce fecund offspring, who are similar in structure and mode of life to their parents.

Similar species of animals are united into a *genus*, similar genera – into a *family*. Families of animals are united into an *order* (there is no such group in botany), and orders – into *classes*. A *phylum* is the largest group of animals. It unites several classes. For example, the sand and viviparous lizards are two different species of animals belonging to one genus. These lizards are related to one family, and are united with families of other lizards and snakes into the order Squamata. This order and related orders of crocodiles and turtles are united into the class Reptilia. All the reptiles, as well as birds, fishes, amphibia, and beasts are included in a large group of animals: the phylum Chordata.

Animals are not united into groups at random, but according to a strict scientific system which is based on detailed and comprehensive research. We hope that you will learn from this textbook about the major systematic groups of animals and their main representatives.

? △

1. What is the role of animals in nature and for man?
2. What are the main features that distinguish animals from plants?
3. Give examples of names of plant and animal species you know.
4. Examine the examples of animal classification on the inside cover at the end of the book.

1 Unicellular Animals

Phylum: Protozoa

Class: Rhizopoda

1.1 Amoeba

MODE OF LIFE, STRUCTURE AND LOCOMOTION. The amoeba is a bottom dweller and is usually found in the ooze in slow-moving or still-water ponds. It looks like a tiny (0.2-0.5 mm), hardly visible, colourless jelly-like clot, constantly changing its shape. The word "amoeba" means "to change". The details in the structure of an amoeba are visible only through a microscope.

The body of an amoeba is comprised of a semi-fluid *cytoplasm* containing a small bubble-like *nucleus*, i.e. it is a cell. An amoeba, like other protozoa, consists of one cell, but this cell is an integral organism, leading an independent life.

The cytoplasm is in constant motion. If the current in the cytoplasm flows toward a certain spot on the amoeba's surface, a bulge appears at this spot. It increases in size and turns into a projection – a *pseudopod*. The cytoplasm flows over into the pseudopod and the amoeba moves in the respective direction. The amoeba and other protozoa capable of forming pseudopodia belong to the class Rhizopoda. This name has been attributed to them because of the external resemblance between pseudopodia and plant roots.

NUTRITION. The amoeba may form several pseudopods at once and it uses them to encircle bacteria, algae, other protozoa. The prey is enclosed in the cytoplasm, a bubble is formed, which is a *food vacuole*. Digestive juices diffuse from the cytoplasm into the vacuole.

The digestive juices dissolve a part of the substances contained in the food and digest them. The dissolved nutrients seep from the vacuole into the cytoplasm and are used for building the amoeba's body. As a rule, the food is not assimilated completely and the undigested remains are ejected through any point on the amoeba's body.

RESPIRATION. An amoeba breathes in oxygen dissolved in the water. The oxygen diffuses into the cytoplasm through the entire surface of the body, and helps to decompose the compound substances of the cytoplasm into more simple ones. Energy, which is necessary for the vital activities of the organism, is produced in this process. Simultaneously, carbon dioxide and other substances that are harmful for the amoeba accumulate in the cytoplasm.

← Protozoa in a drop of pond water (under a microscope)

EXCRETION OF WASTE PRODUCTS AND EXCESS WATER. Harmful substances are excreted from the amoeba's organism through its body surface and through a special bubble – a *contractile vacuole*. The water surrounding the amoeba diffuses into the cytoplasm and dilutes it. Excess water, containing dissolved carbon dioxide and other harmful substances, fills up the vacuole that gradually increases in size, and then ruptures and disappears. Thus the contractile vacuole periodically rids the amoeba of excess water and harmful substances.

Thus, food, water and oxygen enter the organism of the amoeba from the environment. These substances are subjected to changes as a result of the vital activities of the amoeba. The digested food is used as material for building the amoeba's body. Carbon dioxide and other harmful substances are produced and eventually eliminated from the amoeba's body. *Metabolism* occurs. Neither an amoeba, nor any other living organism can exist without metabolic exchange inside the body and with the environment.

REPRODUCTION. Nutrition is responsible for growth of the amoeba's body. An adult amoeba starts to reproduce. Reproduction begins with changes in the nucleus. The nucleus elongates and divides by a transverse

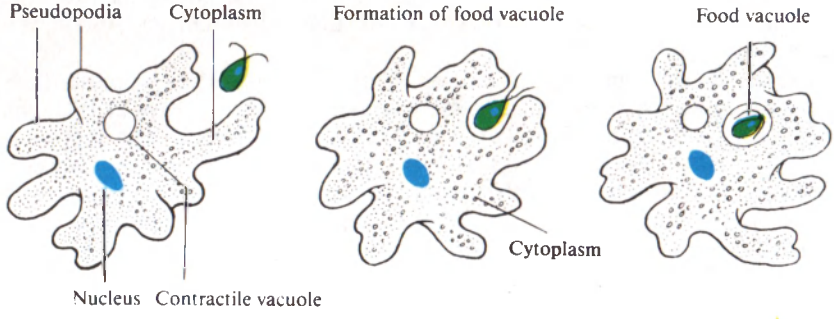


Fig. 1. Nutrition and locomotion of an amoeba. Diagram

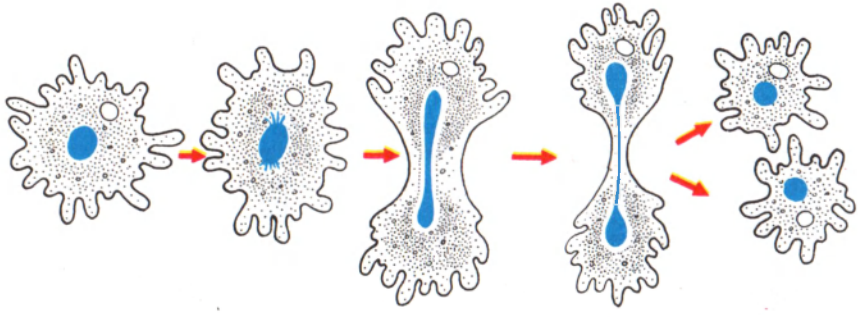


Fig. 2. Fission of an amoeba. Diagram

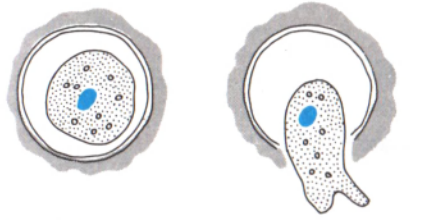


Fig. 3. An encysted amoeba (strong magnification)

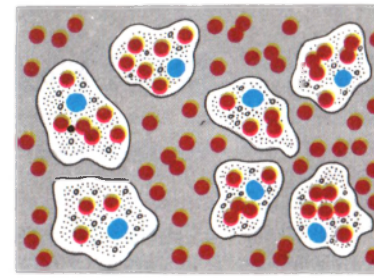


Fig. 4. Dysentery amoeba (strong magnification)

furrow into two halves that separate. The cytoplasmic mass elongates too and grows narrower between the two newly formed nuclei, forming a bridge that breaks and thus two daughter amoebas are appeared. The contractile vacuole remains in one of them and a new one develops in the other. Thus, the amoeba reproduces by binary fission. Fission may occur several times daily.

CYST. Nutrition and reproduction of the amoeba continue throughout the whole summer. The amoeba stops feeding in autumn, when it turns cold. The amoeba's body rounds up and its surface is covered with a thick protective envelope, thereby forming a *cyst*. The same happens if a pond in which amoebas are living dries up. The amoeba endures adverse environmental conditions in an encysted form.

The amoeba emerges from the cyst envelope when the environmental conditions turn favourable. It thrusts out pseudopodia, starts to feed and reproduce. Cysts are carried over land by winds, thereby amoebas are settled in new areas.

DYSENTERY AMOEBA. Several other species are known beside the amoeba. The dysentery amoeba externally resembles the amoeba but differs from the latter by its very short pseudopodia. When drinking contaminated water, the dysentery amoebas enter the intestine of a man, reproduce rapidly, penetrate into the intestine walls and form ulcers. These amoebas feed on destroyed parts of the intestine wall and on blood, causing a serious disease – amoebic dysentery.

? △

1. Where do amoebas live and how do they move around?
2. How and what does an amoeba and a dysentery amoeba feed on? (Use Figures 1 and 4 in your answer.)
3. How are harmful substances eliminated from the body of an amoeba?
4. Use Figure 2 to tell us about the reproduction of an amoeba.
5. What is the significance of a cyst for an amoeba?

1.2 Euglena and Volvox

MODE OF LIFE AND LOCOMOTION OF AN EUGLENA The euglena, like the amoeba, inhabits ponds contaminated with rotten leaves. It occurs also in pools and other stagnant water bodies. The euglena's body length is about 0.05 mm and is somewhat elongated. Its anterior end is blunt while the posterior portion is pointed. The external layer of the euglena's cytoplasm is dense and forms an *envelope* around the animal's body. The body form of the euglena changes very little during locomotion owing to this envelope. The euglena can only contract slightly, becoming shorter and wider. There is a thin thread-like extrusion from the cytoplasm, called a *flagellum*, at the anterior end of the euglena's body. The euglena rotates the flagellum, as if screwing itself into the water, and as a result it swims with its blunt end forward.

Protozoa, who move with the help of one or several flagella, belong to the class flagellata.

Scientists believe that all the classes of modern protozoa originated from ancient flagellates, who lived about 1.5 billion years ago.

NUTRITION. The cytoplasm contains more than 20 green oval chloroplasts that make it green. The chloroplasts contain chlorophyll. The euglena feeds like green plants, building its body of organic substances formed in the presence of light by photosynthesis. Tiny grains of reserve nutrients accumulate in the cytoplasm. These grains are similar to starch in composition and the euglena consumes them when it is starving.

If placed for a long time in darkness, the chlorophyll disappears and the animal turns colourless. Photosynthesis ceases in this case and the euglena

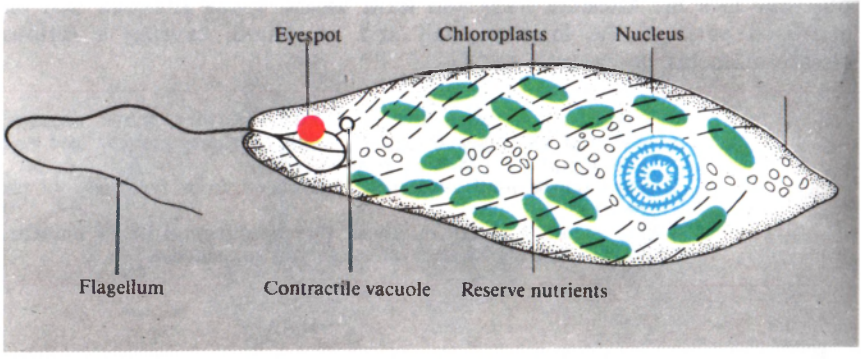


Fig. 5. Structure of euglena. Diagram

begins to assimilate dissolved organic substances which form in various decaying dead organisms.

RESPIRATION AND EXCRETION occur in the euglena in the same way as in an amoeba. The contractile vacuole is at the anterior end of the euglena's body. The euglena uses it to eliminate excess water and wastes.

METABOLISM. The euglena feeds by two different ways and its body metabolism depends on the method of feeding. Metabolism in the darkness is the same as in an amoeba and other animals. The nature of metabolism changes in the presence of light and becomes the same as in green plants. This peculiarity in the metabolism of an euglena, as well as the similarity to the structure of plant and animal cells, indicates the relationship between plants and animals.

SENSITIVITY TO LIGHT. A bright-red light-sensitive *eyespot* is near the contractile vacuole in the euglena, who always swims toward the illuminated part of the water, i.e. where the conditions for photosynthesis are most favourable.

REPRODUCTION. A large nucleus is visible in the cytoplasm nearer to the posterior end of the euglena's body. It divides into two parts during reproduction. The nuclei being formed move apart and fission of the body begins. At first a new flagellum grows near the existing one. A furrow forms between them at the anterior end of the body. It becomes deeper and deeper and passes between the nuclei. Two young euglenas are formed as a result of this division.

CYST. A cyst forms around the euglena under unfavourable environmental conditions, as in an amoeba. The flagellum drops off, the euglena's body rounded up and covered with a protective envelope. The euglena spends the winter in this state or endures the drying up of the water that it inhabits.

VOLVOX—A COLONY OF FLAGELLAR PROTOZOA. Green balls about 1 mm in diameter occur swimming in ponds and lakes. The ball is a volvox. It is seen through a microscope that the ball consists of numerous (about 1000) cells, resembling an euglena in structure.

Fig. 6. Fission of euglena. Diagram

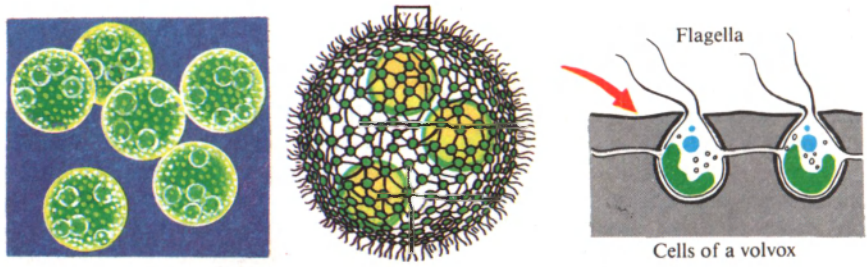


Fig. 7. Volvox (magnified). Structure of a colony. Diagram

Unlike an euglena, the cells of a volvox are pear-shaped with two flagella. The basic mass of the ball is a semi-liquid jelly-like substance. The cells are submerged into it at the very surface so that the flagella stick out. The volvox rolls over in the water owing to the motion of the flagella ("volvox" means "to roll").

Each cell of the volvox looks like an independent protozoan, but all together they form a *colony*, because they are interconnected by *cytoplasmic bridges*. This explains the coordinated activity of the flagella in the entire colony.

Some cells submerge deep into the ball during reproduction of the volvox, where division occurs with the formation of several new young colonies that emerge from the old volvox.

? △
1. What protozoa belong to the class Flagellata?
2. What are the similarities and differences between the structures of an amoeba and an euglena? (Use Figures 1 and 5 in your answer.)
3. What specific features in the structures and vital activities of an euglena make it similar to plants, and what – to animals?

Class: Infusoria

1.3 Paramecium

MODE OF LIFE, STRUCTURE AND LOCOMOTION OF A PARAMECIUM. *Paramecium* is an active, slipper-shaped animal with a length of 0.1-0.3 mm. Like amoebas and euglenas, it is common in most fresh water bodies that contain vegetation and decayed organic matter. It preserves a constant body shape owing to the dense external layer of its cytoplasm. The entire surface of the infusorian's body is covered with longitudinal rows of numerous tiny cilia, whose structure resembles the flagella of an euglena and a volvox. The cilia perform wave-like motions and the *Paramecium* swims with its blunt end forward.

Protozoa, which moves by numerous cilia, belong to the class Infusoria. An infusorian was discovered for the first time in water infused on different herbs.

NUTRITION. An oral groove lined with strong cilia extends from the anterior to the middle of the *Paramecium's* body. At the posterior end of the groove a *mouth* opens into a short tubular *gullet*. The continuously beating cilia in the groove create a water current. The water brings the main food of the *Paramecium*, namely, bacteria, to its mouth. The bacteria enter the infusorian's body through the gullet. Here, in the cytoplasm, a food vacuole is formed around the bacteria, wherein digestive juices are secreted. The cytoplasm of a *Paramecium* is in constant motion, like that of an amoeba. The vacuole tears off from the gullet and is transported by the cytoplasmic flow. The food is digested and the nutrients are assimilated in an infusorian like in an amoeba. Undigested remains are ejected through the *cytoproct*.

Respiration and ejection occur in *Paramecia* like in other protozoa discussed earlier. Two contractile vacuoles in the *Paramecium* (anterior and posterior) contract alternately every 20-25 seconds. Water and harmful by-products of vital activities are accumulated from the cytoplasm and supplied through *radiating canals*, which empty into the contractile vacuoles.

REPRODUCTION. The cytoplasm of a *Paramecium* contains a micronucleus and a macronucleus. The function of each nucleus is different. The micronucleus is of primary significance in reproduction, while the macronucleus effects the processes of locomotion, nutrition, excretion.

The *Paramecium* feeding intensively in summer, grows and divides into two parts, like an amoeba. The micronucleus moves apart from the macronucleus and divides into two parts that move to opposite ends of the body. Then the macronucleus divides. The *Paramecium* stops feeding; its body constricts

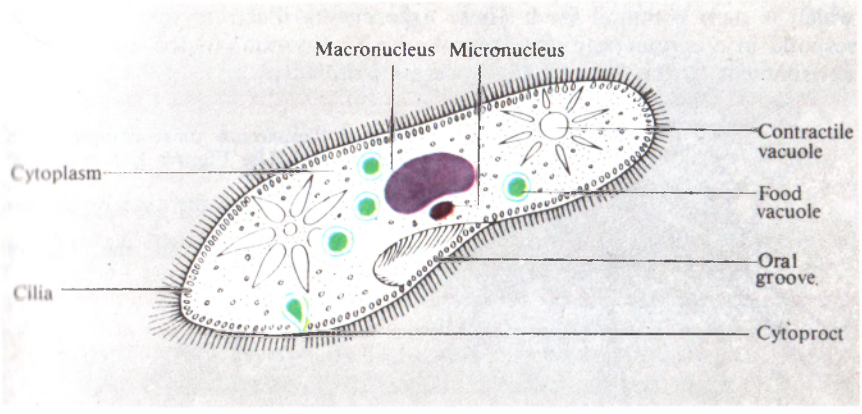


Fig. 8. Structure of *Paramecium*. Diagram

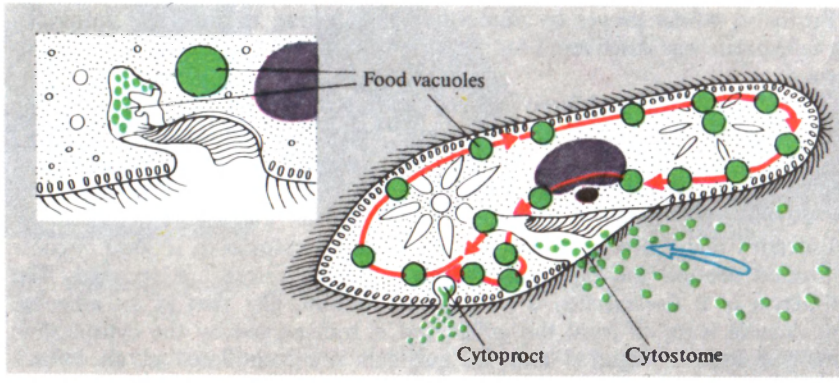


Fig. 9. Nutrition of *Paramecium*. Diagram

transversely in the middle. The newly formed nuclei move to the anterior and posterior ends of the animal. The constriction becomes tighter and finally both halves separate and form two young infusorians. Each young animal contains one contractile vacuole and a second one forms along with the entire system of canals. The *Paramecia* begin to grow when they start to feed. Division occurs again on the next day.

IRRITABILITY. Let's do the following experiment. We place a drop of pure water and a drop of water with infusorians next to one another on a glass plate; then we connect both drops by a thin water canal. We put a tiny crystal of salt into the drop with infusorians. While the salt is dissolving, the *Paramecia* swim over into the drop with pure water: a saline solution is harmful for infusorians.

Now we'll change the conditions of the experiment. We do not add anything into the drop with infusorians, but we add some infusion with bacteria into the other drop, and the *Paramecia* gather around the bacteria which is their common food. These experiments illustrate that infusorians respond in a certain way (for example, by locomotion) to the effect of the environment (irritation), i.e. they possess *irritability*.

?

1. What makes the structure of a *Paramecium* more complex than that of an amoeba and an euglena? (Use Figures 1, 5, and 8 in your answer.)

△

2. How does a *Paramecium* feed? Tell us about the digestive process in the animal.
3. What is the significance of stimulation in the life of a *Paramecium*?

1.4 Diversity and Significance of Protozoa

More than 30 000 species of protozoa occur in water and in the soil. Some of them settle in the bodies of other animals and in the human organism.

MARINE RHIZOPODS. The body of a protozoan, that, like an amoeba, belongs to the class of Rhizopods, is encased in a thin calcareous shell. The shape of the shell is different in each species of rhizopods. Marine rhizopods are one of the most ancient animals, some of their species lived millions of years ago. When such rhizopods perished, their shells accumulated on the sea bottom, which resulted in the gradual formation of limestone deposits,

Fig. 10. Chalk as viewed through a microscope

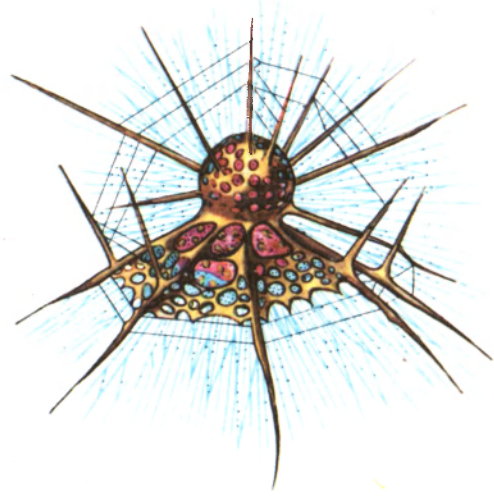


Fig. 11. Radiolarian (magnified)

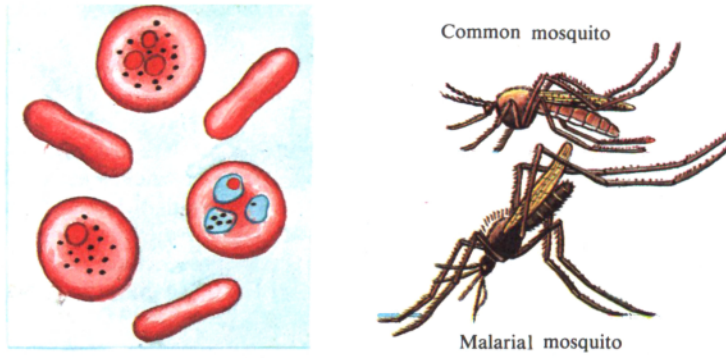


Fig. 12. Human blood cells infected by malarial parasite. To right: mosquitoes: common and malarial (disease carrier).

a valuable building material. The chalk used for writing on the blackboard in the class, and also for whitewashing walls and ceilings in buildings, consists of the shells of marine rhizopods.

Extinct marine rhizopods are important also from another point of view: the discovery of some species indicates that an oil deposit may be nearby. Therefore, geologists, who explore for useful minerals, look for rhizopods.

Radiolaria, another type of marine rhizopods, are encased in shells of beautiful shapes, resembling tiny stars, snow-flakes, thorny balls and other figures. Shell clusters of extinct radiolaria sometimes form considerable deposits. They are exploited and used for grinding and polishing metals, for making emery paper.

MALARIAL PARASITES. Some protozoa are called *parasites*. They settle in the organisms of animals and men, who become in this case the *hosts* of the parasites. You are already familiar with one parasitic protozoan, namely, a dysentery amoeba. A serious disease of men, malaria, is caused by a malarial parasite which settles in the blood. The temperature of a patient sick with malaria rises to 40-41 °C every 2-3 days. Pathogens of malaria are microscopically small. They penetrate into the red blood cells of human blood. The malarial parasite, resembling an amoeba by its shape, feeds, grows, and reproduces there by division, destroying the blood cells and secreting poisonous substances in the blood. The disease is transmitted from sick people to healthy ones by malarial mosquitoes. It is easy to distinguish this mosquito from the common one by the characteristic pose it takes when it sits and sucks blood. Millions of people, inhabiting mainly tropical countries, are sick with malaria. Years ago many people were sick with malaria in the southern regions of the USSR, especially in Soviet Central Asia. Malaria has virtually been eliminated in our country during recent years.

?
△

1. What is the practical significance of protozoa?
2. What animals are called parasites, and what – hosts of parasites?
3. Examine the diagram of the evolution of the animal world on the front inside cover. Determine the place occupied by the classes of the phylum Protozoa.

■

Take some hay, cut it up into minute particles, put it into a jar with water from a pond or a river. Put the jar in a warm place. Examine a drop of this infusion under a microscope 10 days later. Draw the familiar protozoa that you see under the microscope.

2 Multicellular Animals

Phylum: Coelenterata

2.1 Hydra–a Freshwater Polyp

EXTERNAL STRUCTURE AND MODE OF LIFE. The hydra, a tiny semi-transparent animal, occurs on stems of aquatic plants in lakes, rivers, or ponds with pure, clear water. (The word "polyp" means "many feet" and it is used in zoology to name attached or sedentary coelenterates with numerous *tentacles*.) The body of a hydra is almost of a perfect cylindrical shape. The mouth is at one end and is surrounded by a set of 5–12 thin long tentacles, while the aboral end is elongated like a stalk with a *base* at the end. The hydra uses the base to attach itself to various underwater objects. The body of the hydra together with the stalk is usually not longer than 5–7 mm, but the tentacles can stretch out to several centimeters.

RADIAL SYMMETRY. If an imaginary axis is drawn along the hydra's body, the tentacles radiate to all sides like beams from a light source. This arrangement of the body parts in a hydra or other animals is called *radial symmetry*. Suspending from an aquatic plant, a hydra swings continuously from side to side with its tentacles slowly moving around in wait for some prey. A victim may appear from any side, therefore radiating tentacles are the best for this method of hunting.

GASTROVASCULAR CAVITY. The body of a hydra is like a sac whose walls consist of two layers of cells: the external one – the *epidermis*, and the internal – the *gastrodermis*. The gastrovascular cavity in the body of the polyp is called the *enteron* or *coelenteron* (hence, the name of the phylum: coelenterata).

EPIDERMIS. Several types of cells are visible in the epidermis of a hydra if examined under a microscope. The majority are *epitheliomuscle cells*. Contacting the lateral sides, these cells create the covering of the hydra. A *muscle fiber*, which is very important for the locomotion of the animal, is at the base of each epitheliomuscle cell. When the fibers of all epitheliomuscle cells contract, the body of the hydra compresses. If the fibers contract only on one side of the body, the hydra bends to that side. Owing to the muscle fibers the hydra can move slowly from place to place, "stepping" alternatively on the base of its foot, and on the tentacles.

← Representatives of the animal world: *1* – Hydra, *2* – Wild boar, *3* – Mouse, *4* – Butterfly, *5* – Buzzard on a nest, *6* – Horses

The *nerve cells* are in the epidermis. They are star-shaped and therefore they have long outgrowths. The outgrowths of neighbouring nerve cells touch one another and form a *nerve network*. Some of the outgrowths approach the epitheliomuscle cells.

IRRITABILITY. REFLEXES. A hydra responds to tactile stimulation, changes in temperature conditions, the appearance of various dissolved substances in the water, and other kinds of stimuli, and, as a result, the nerve cells are stimulated. If a hydra is touched with a thin needle, the stimulus at one nerve cell is transmitted via the outgrowths to the other nerve cells and still further to the epitheliomuscular cells, causing contraction of the muscle fibers, whereas the hydra rolls itself into a ball.

This example illustrates a complex phenomenon in the organism of the animal – a *reflex*. A reflex consists of three successive stages: the *perception of stimulus*, the *transmission of the excitation* evoked by this stimulus via the nerve cells, and the *response reaction of the organism* in the form of some action. The reflexes of a hydra are quite monotonous because of the simple organization of its organism. We shall later encounter more complicated reflexes in more highly organized animals.

STINGING CELLS. The whole body of a hydra and especially its tentacles contain a large number of *stinging cells* that are also known as *nettle cells*.

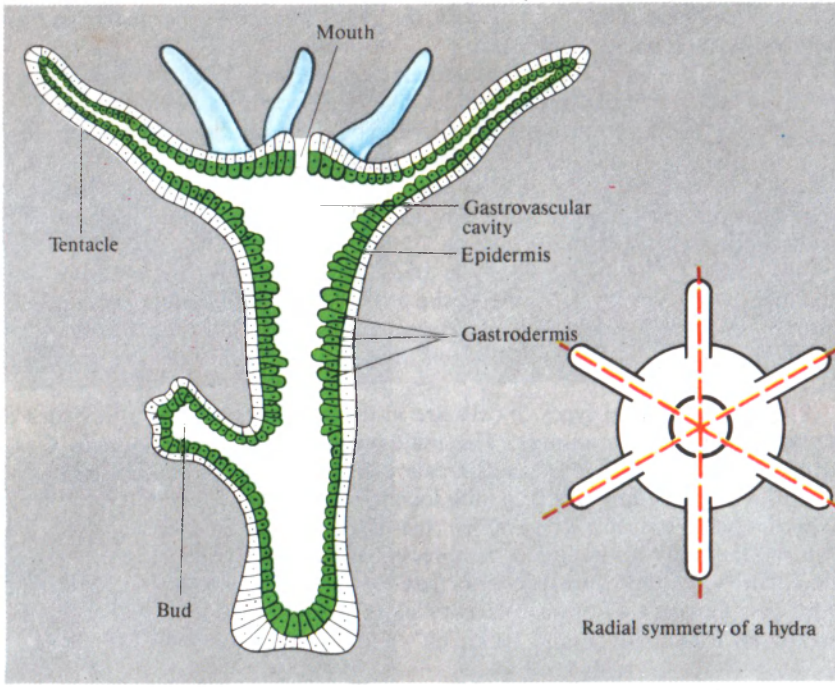


Fig. 13. Structure of a freshwater hydra. Diagram

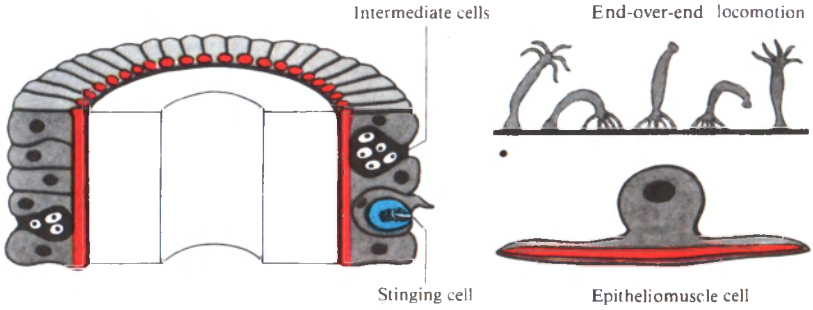


Fig. 14. Structure of a hydra's body epidermis. Diagram

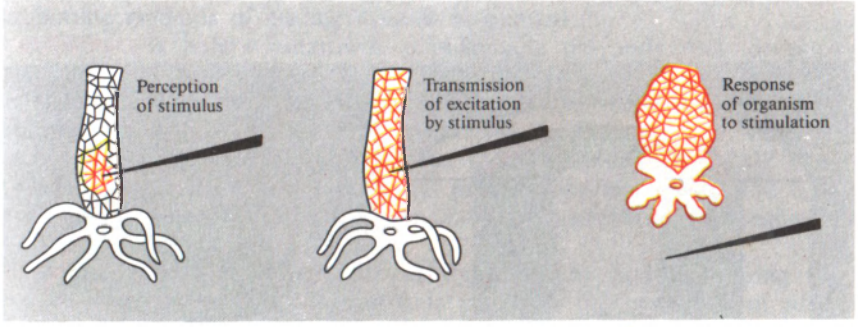


Fig. 15. Stimulation of a hydra. Diagram

The structure of these cells is quite complicated. Besides the cytoplasm and nucleus, it contains a bubble-like *stinging capsule* which contains a thin coiled tube that is called a *stinging thread*. A *sense hair* extends outside the cell. If a small crustacean, a water flea, young fish or some other small aquatic animal comes in contact with the sense hair, the stinging thread immediately straightens out and its end stings the prey. A toxin, causing death in small animals, is discharged from the stinging capsule and via a canal, contained in the thread, enters the prey. As a rule, many stinging cells discharge simultaneously. Then the hydra uses its tentacles to bring the trapped prey to the mouth, where it is ingested.

The hydra uses the stinging cells also for defense. Fishes and aquatic insects abstain from feeding on hydras because of the burning effect of their poison. The effect of the poison on the organism of big animals resembles the effect of nettle toxin.

GASTRODERMIS. The cells in the gastrodermis possess contracting muscle fibers, but the major role of these cells is to digest food. They secrete digestive juices into the gastrovascular cavity, which softens the prey of the hydra and reduces it to a fine particulate condition. Some of the cells in the gastrodermis possess several long flagella (like in flagellar protozoa). The

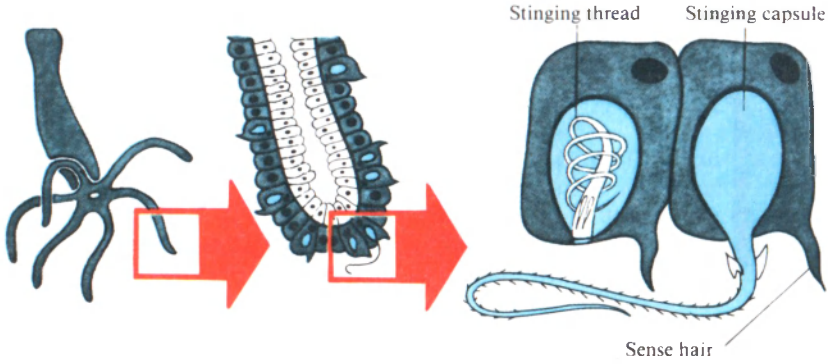


Fig. 16. Stinging cell of a hydra. Diagram

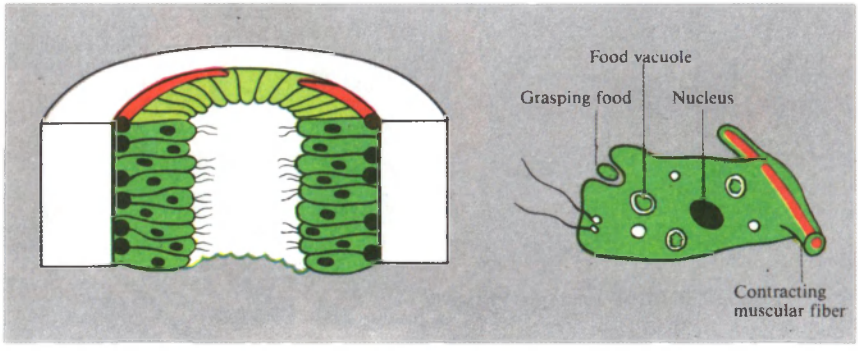


Fig. 17. Structure of a hydra's gastrodermis. Diagram

flagella are in constant motion and carry food particles to the cells. The cells of the gastrodermis are capable of letting out pseudopodia (like an amoeba) to grasp the food. Subsequent digestion is completed inside the cell, in vacuoles (like in protozoa). Undigested remains are regurgitated through the mouth. The hydra lacks special respiratory organs and the oxygen dissolved in the water diffuses into the animal through the entire body surface of the hydra.

? △

1. How does a hydra find food?
2. What is the role of the stinging cells in the life of a hydra (Figure 16)?
3. Where does digestion occur in a hydra?
4. Draw a hydra by memory and name the parts of its body.
5. Tell us about the structure of a hydra. (Use Figures 13 and 14 to do this.)

2.2 Reproduction of a Hydra

REGENERATION. Small rounded cells with large nuclei are also contained in the epidermis. These cells are called *intermediate cells*. They play an important role in the life of a hydra. If the body of a hydra is mutilated, the intermediate cells near the wound begin to grow intensively, giving birth to epitheliomuscle, nerve and other cells, whereas the wounded spot heals rapidly.

When a hydra is cut in half, tentacles grow and a mouth appears on one half, while a stalk develops on the other. Now there are two hydras.

This process of recovering lost or mutilated parts of the body is called *regeneration*. The regeneration power of a hydra is very highly developed. Scientists-biologists and physicians study the laws of regeneration using hydra as an example. Knowledge of these laws is very important for elaborating methods of healing wounds in humans.

BUDDING. A hollow outgrowth – a bulging in the body wall – develops very often on the body of a hydra. The outgrowth grows and stretches. Tentacles appear at its end and a mouth breaks open between them. Thus, a new young hydra develops, being connected for a certain time with the mother by a stalk. The process resembles the development of a stalk from a plant's bud (hence the name of this process – *budding*). When the little hydra grows up, it detaches itself from the mother organism and begins to live independently.

REPRODUCTIVE PROCESS. Hydras reproduce by budding during the warm season of the year. The animals perish at the beginning of unfavourable conditions in autumn, but sex cells develop in their body before that. There are two types of sex cells: ova or female gametes, and spermatozoa or male sex cells. *Spermatozoa* resemble flagellar protozoa. They leave the body of a hydra and swim around by means of a long flagellum.

The *ovum* of a hydra resembles an amoeba. It possesses pseudopods and develops very fast, consuming the neighbouring intermediate cells. The spermatozoon swims up to a hydra with an ovum and penetrates into the latter, evoking fusion of the nuclei of both sex cells. *Fertilization* occurs. The pseudopods retract, the cell rounds up and a thick sheath develops on its

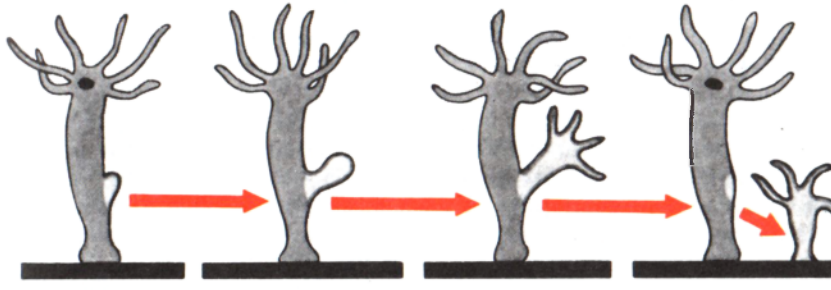


Fig. 18. A budding hydra. Diagram

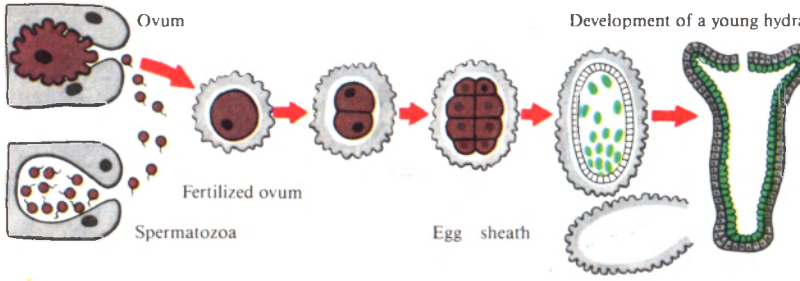


Fig. 19. Sexual reproduction of a hydra. Diagram

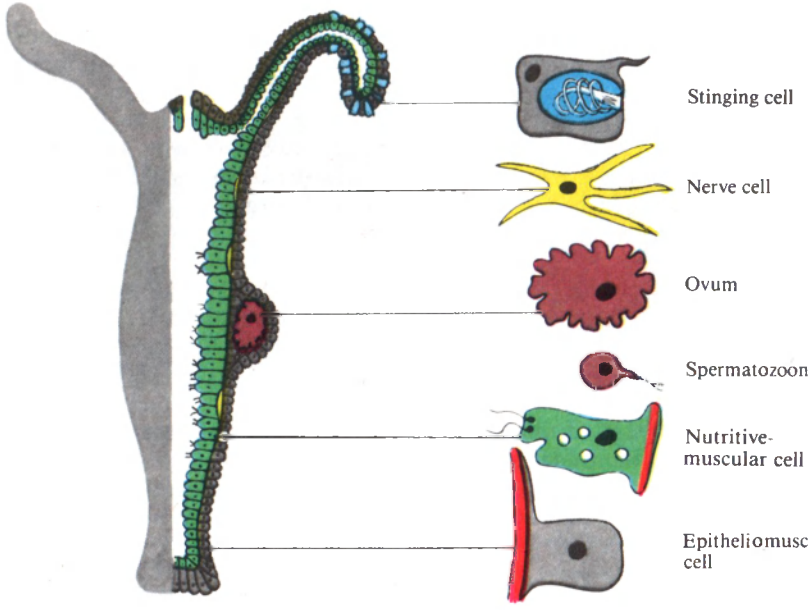


Fig. 20. Look at the drawing. Use it to repeat the structure of a hydra and the names of its individual cells

surface, thereby forming an *egg*. When the hydra perishes, the egg remains alive and drops to the bottom. The living cell inside the protective sheath begins to divide in spring and the forming cells arrange themselves in two layers. A little hydra develops from them. It emerges through a rupture in the egg sheath at the beginning of the warm season.

Thus, the hydra, a multicellular animal at the beginning of its life, consists only of one cell – an egg. This means that the ancestors of the hydra were unicellular animals.

? 1. How does a hydra reproduce during the warm season of the year?

△ 2. What are the similarities and differences between the reproduction of a hydra and a *Paramecium*?

3. The sex cells of a hydra are similar to what protozoa? What conclusion may be drawn from this?

2.3 Marine Coelenterata

The phylum coelenterata comprises about 9000 species, the majority of which occur in seas.

POLYPS. Large polyps, sea anemones, inhabit the sea living among stones and rocks. They are usually brightly coloured and possess several sets of short thick tentacles. Sea anemones stay immobile in rock clefts in wait of some prey, or creep slowly on the bottom, using the tentacles to grasp sedentary animals that they feed on.

FORMATION OF COLONIES. When a young polyp buds into a marine coelenterate, it does not pinch off like a hydra from the mother's organism but remains connected to it and soon begins to bud new polyps itself, thereby forming a colony. The gastrovascular cavities of polyps are interconnected and the food grasped by one of them is assimilated by all the members of the colony. A skeleton usually develops in colonial polyps, consisting most often of lime. The skeleton of red coral is used for making beads and other ornaments.

CORAL REEFS. Some species of colonial polyps form dense settlements of coral reefs in the shallow waters of tropical seas. Colonies of corals, possessing very strong calcareous skeletons, create obstacles for navigation.

Reef-building corals (!) are frequently restricted to the shores of islands, surrounding them on all sides. If the sea bottom recedes and the island sinks, the corals continue to grow and remain on the sea surface. These ring-like reefs later form islands, atolls, that are characteristic of tropical seas. The skeletons of reef-building corals are used for the production of lime. Underwater reserves are organized sometimes on coral reefs, where the corals are protected as rare valuable representatives of the animal world.

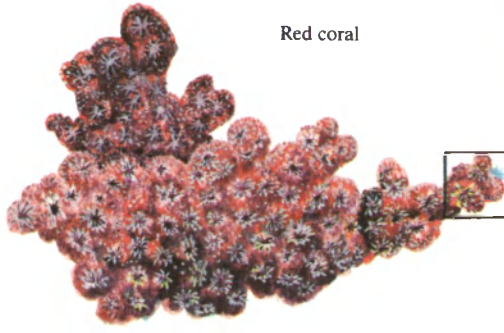
JELLYFISH. Not all the coelenterates dwell on the bottom, some of them swim in the water, for example, jellyfish. The jelly-like body of a jellyfish is shaped like an umbrella with the mouth in the center of the underside (subumbrellar surface) of the umbrella. At the margin of the umbrella hang tentacles. Contracting its umbrella sharply and forcing the water outward, the jellyfish propels forward with its convex side in front. Jellyfish are predators like all other coelenterates. They kill their prey by means of their stinging cells. A human may experience quite considerable or sensitive burns if stung by some jellyfish. One must beware of certain jellyfish (Rhizostoma) in the Black Sea, whose semi-transparent, whitish umbrella reaches the size of a football with bright-violet or blue edges.

Sea anemone

Jellyfish aurelia

Jellyfish
Rhizostoma

Red coral



A branch of a red coral
(magnified)

Fig. 21. Marine coelenterates

?

△

1. What is the difference between the budding of hydras and the formation of coral colonies?
2. How do jellyfish move around?
3. Find the location of the phylum coelenterata in the diagram of the evolution of the animal world (front inside cover). List the major characteristics of the phylum.

Phylum: Platyhelminthes (Flatworms)

Class: Turbellaria

2.4 White Planarian

EXTERNAL STRUCTURE AND MODE OF LIFE. White planarians, 1–2 cm long worms, occur in ponds or brooks which have stones. Planarians lead a concealed mode of life, hiding under leaves, under the bark of stumps, and under stones. Its intestine, stuffed with dark food, is visible through the skin.

A planarian's body in its common state is extended in length and dorsoventrally flattened (hence the name of the plylum: flatworms). However, the slightest stimulation (for example, a touch) causes a sharp contraction of the body, indicating that the musculature is well-developed in the planarian. The posterior of the planarian is pointed and the anterior is broad with lateral projections, which have a tactile function. Two black eyes are on the anterior dorsal surface of the body. The planarian creeps by a gliding movement on the bottom of a water bed, and sometimes it lifts itself into the water mass and swims there for a short time. The planarian's body is covered with cilia. The locomotion of the planarian is smooth owing to the coordinated motion of the cilia.

BILATERAL SYMMETRY. If you look at a planarian, you can see that its left-hand side is a mirror image of the right-hand side. All the organs of the planarian are also arranged in strict order on both sides of an imaginary

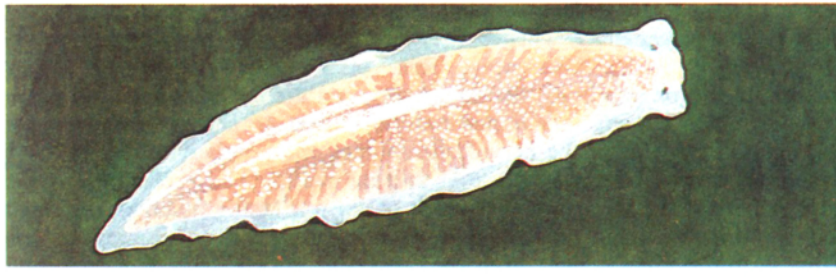


Fig. 22. White planarian (magnified)

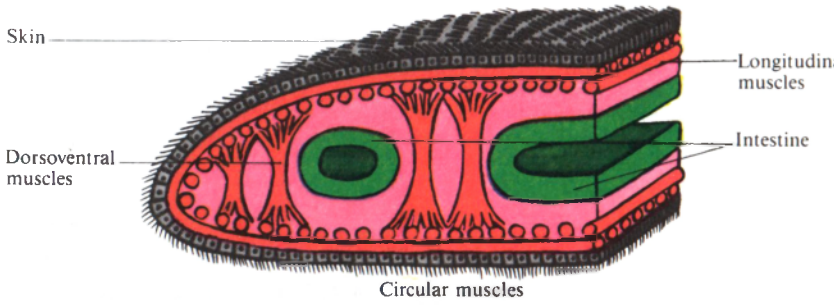


Fig. 23. Arrangement of muscles in a planarian. Diagram

plane, which runs along the body of the animal. This type of symmetry is called *bilateral*, unlike radial symmetry in coelenterates. Bilateral symmetry is characteristic of the majority of multicellular animals. It evolved in connection with these animals' capacity for active locomotion.

MUSCULATURE. A planarian possesses circular and longitudinal *muscles* that make it possible for the animal to change its body shape and move around. Furthermore, muscle fibers are located between the dorsal and ventral sides. When these fibers contract, the body of the planarian flattens.

INTESTINE AND NUTRITION. The mouth of the planarian is located ventrally in the middle of the body. It leads to a long muscular pharynx that may protrude outside through the mouth. Three branches of the *intestine* start from the pharynx: one is directed forward, while two others bend backward along the sides of the pharynx. Each branch divides into a set of smaller branches ending blindly.

A predatory planarian feeds on tiny aquatic animals that crawl on the bottom of water beds. The animal covers the prey with its body and thrusts out its pharynx, which pierces the prey. Then the planarian sucks in and digests the contents of its pharynx. Undigested remains are discharged through the mouth opening.

RESPIRATION. The oxygen dissolved in the water penetrates into the organism of a planarian through the entire surface of its body. The forming carbon dioxide is also eliminated through the entire body surface.

EXCRETION. The body of the worm is permeated with numerous thin system of canals (*branching tubules*). Harmful liquid by-products of vital activity enter the canals, whence they are discharged via *excretory pores*.

NERVOUS SYSTEM. The nerve cells of a planarian do not occur throughout the worm's body, like in a hydra, but are collected into *two nerve trunks*. The nerve trunks are united anteriorly into an enlargement – a *nerve ganglion*. Outgrowths of the nerve cells contact one another tightly, forming nerve intersections between the trunks and the nerves. The projections in the anterior part of the worm's body, which perform a tactile function, are most densely furnished with nerves. Special nerves extend to the eyes. The planarian discriminates light from darkness and crawls away from brightly illuminated spots to the shade.

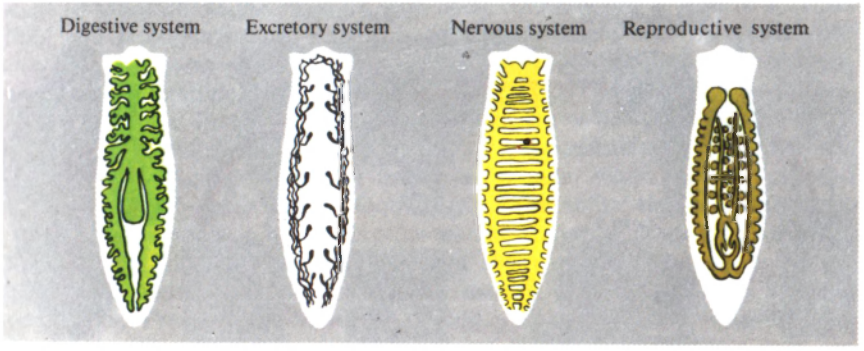


Fig. 24. Internal structure of a white planarian. Diagram

REGENERATION. The regenerative capacity of a planarian is quite highly developed, like in a hydra.

REPRODUCTION. Two oval bodies – *ovaries* – are in the anterior part of the planarian's body, and numerous bubbles – *testes* – are also located in the worm's body. These are the *reproductive organs.*

Eggs develop in the ovaries, and spermatozoa in the testes. Consequently, female and male gametes develop in each planarian. Animals, that simultaneously have female and male organs of reproduction are called *hermaphrodites.*

A planarian does not lay single eggs, it deposits *cocoons*, i.e. small groups of eggs enclosed in a thick casing. Tiny planarians develop from the eggs under the protection of the casing and they leave the cocoon through a rupture in its wall.

1. What sensory organs are known in a planarian?
2. What is the difference between bilateral symmetry and radial symmetry? (Use Figures 13 and 23 to answer the question.)
3. In what way is the nervous system of a planarian more complicated as compared with the nerve plexus of a hydra?
4. What animals are called hermaphrodites?

Class: Flukes

2.5 Liver Fluke

Parasitic flatworms occur in animals and man. The liver fluke is one of these worms. It occurs in the liver of sheep and other animals. The length of the worm's body is 3–4 cm, it is flattened and leaf-like in shape. Its epidermis lacks any cilia. The mouth is at the anterior

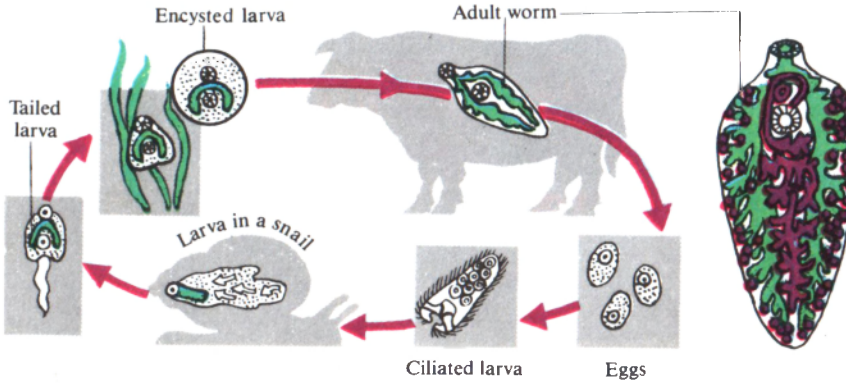


Fig. 25. Development of a liver fluke. Diagram

end of the body. The edges of the mouth are enlarged and form a muscular *oral sucker*. *Ventral sucker* is on the ventral side of the body. The worm uses the suckers to attach itself inside the liver of the host.

The parasite feeds on blood and hepatic cells, sucking in the food via the oral sucker. The food enters the pharynx, which turns into a branching intestine, like in a planarian.

Liver flukes are hermaphrodites. The fertilized eggs are deposited by the worm into the intestine of the host and excreted together with the faeces. The eggs must get in water for their further development. Microscopic ciliated larvae hatch out of the eggs. They bore into the bodies of snails, grow up and reproduce. New, daughter larvae are not ciliated but they have a swimming tail. They leave a snail's body to enter the water, where they swim, attach themselves to aquatic plants, drop their tail and become encapsulated, thereby forming a cyst. The cyst enters the intestine of sheep and other animals together with grass. In the intestine of the cattle a young fluke emerges from the cyst and matures into an adult worm. When drinking contaminated water, a man may swallow a cyst and become infected by the liver fluke.

Class: Tapeworms

2.6 Beef Tapeworm

A beef tapeworm parasitizes in the intestine of man, but its larvae develop in the organism of cattle (hence the name – beef tapeworm).

A tapeworm has a little scolex, or head, a short neck and a long tape-like body (hence the name of the class – tapeworms). Four round muscular suckers are arranged on the scolex and the parasite uses them to attach

itself to the walls of the intestine. The body of the worm is from 4 to 10 m long and is comprised of numerous proglottids (there may be about 1000 species). The worm grows and the number of proglottids increases throughout its entire lifetime. New proglottids are produced in the neck area. They are very small at first, but they enlarge toward the posterior end of the body.

The absence of digestive organs is one of the peculiarities of a tapeworm. The parasite inhabits the small intestines in man, where it finds digested food. The worm sucks in this food through the entire surface of its body.

The tapeworm is a hermaphrodite as the majority of other flatworms. Each proglottid of the tapeworm, except the youngest ones, contains one ovary and numerous testes. The ova mature only in the old terminal proglottids. These proglottids break off and are carried outside together with the faeces. An infected man excretes about 5 000 000 eggs daily.

Cattle may ingest the eggs of a tapeworm together with grass. Microscopic larvae with six hooks hatch out of the eggs in the animal's intestine. The larvae use the hooks to pierce the intestinal walls, then they enter the blood

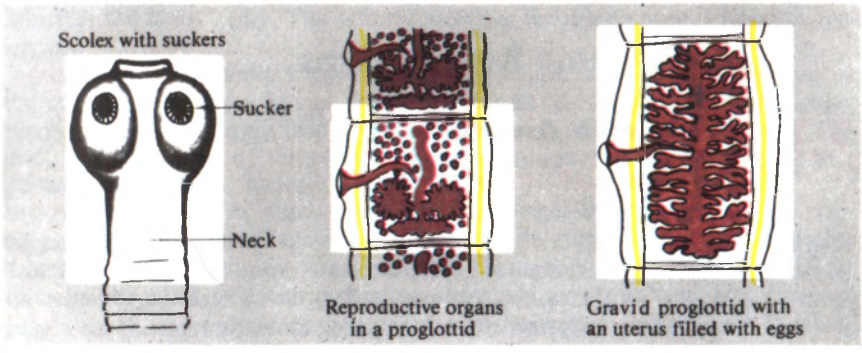


Fig. 26. Beef tapeworm. Structure of scolex and proglottids. Diagram

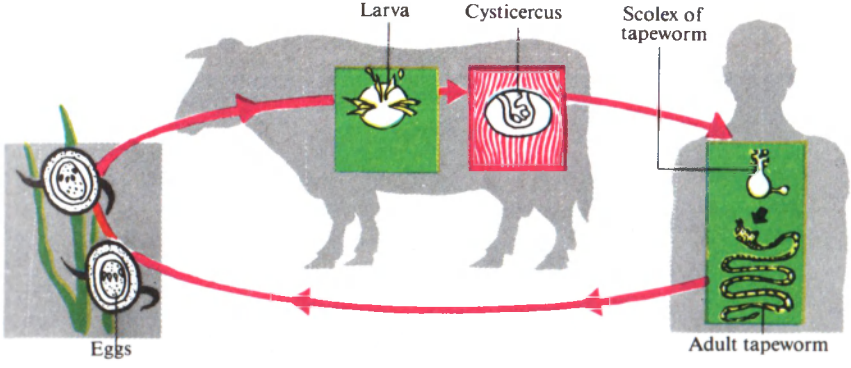


Fig. 27. Development of a beef tapeworm. Diagram

and are carried throughout the whole body of the animal, penetrating finally into the muscles. The six-hooked larvae grows and transforms into a *cysticercus*, which is a pea-sized sac, containing the tapeworm's scolex with the neck.

The cysticerci remain alive in underfried or undercooked meat. If a man consumes this meat, the scolex of the tapeworm everts from the sac and attaches itself to the lining of the intestine. The bladder drops off and the neck begins to grow and form a series of proglottids. The parasite secretes toxic substances, causing diarrhea and anaemia.

? △

1. What are the peculiarities of a beef tapeworm as compared with other flatworms?
2. Use Figure 27 to tell us about the development of the beef tapeworm.
3. What peculiarities in the structure of a tapeworm are associated with its parasitic mode of life?
4. Divide this section into two parts and give a title to each one.

Phylum: Roundworms

2.7 Human Ascarid

EXTERNAL STRUCTURE. The human ascarid, parasitizing the small intestine, is the most common of parasitic worms infecting humans. It occurs more often in children. The ascarid's body is up to 20 cm long and very elongated, gradually narrowing at the ends and with a round cross section (hence the name – roundworms). The white or yellowish body of the ascarid is encased in a smooth tough cuticle.

MUSCULATURE AND LOCOMOTION. A layer of longitudinal muscles is found under the cuticle. The ascarid can bend its body, but it is unable to stretch or contract it. It floats in the intestine of the host, continuously moving toward the incoming mass of food.

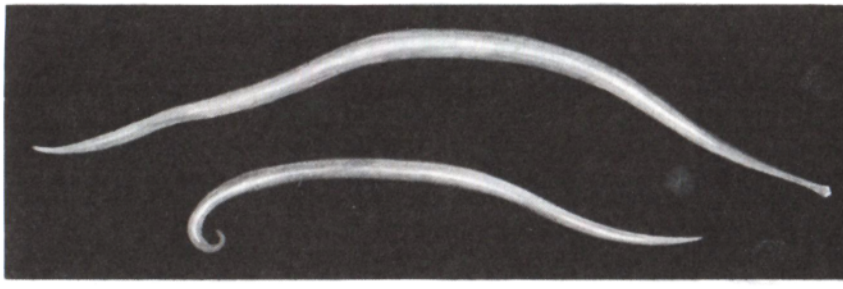


Fig. 28. Ascarid: *above* – female, *below* – male

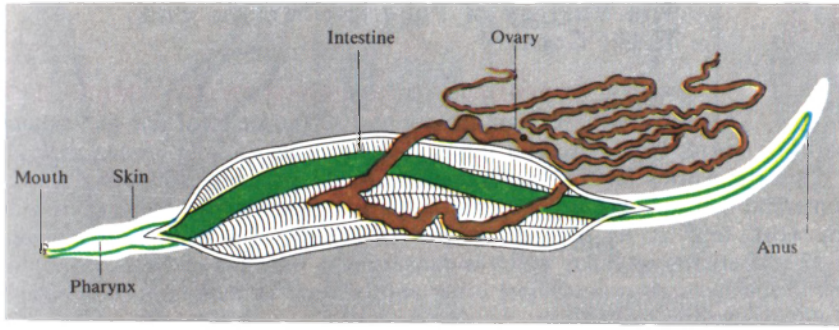


Fig. 29. Dissected ascarid. Diagram

Unlike parasitic flatworms, the ascarid lacks anchoring organs.

BODY CAVITY. The ascarid's body is like a tube closed at both ends, whose walls are formed by an external layer of cells and muscles, within which is the *body cavity*. The latter comprises the digestive and reproductive organs.

NUTRITION. A *mouth* surrounded by three *lips*, is at the anterior end of the ascarid. The food passes from the mouth through a short muscular pharynx and oesophagus into a thin straight tube, which is the *intestine*. The undigested remains of food are removed through the *anal* orifice at the posterior end of the worm's body.

REPRODUCTION AND DEVELOPMENT. Ascarids are *dioecious*. The female has two ovaries, and the male – one testis. The reproductive organs look like long bent tubes. An ascarid is very fertile: every day it lays many thousand eggs, which are coated in very thick sheaths. The eggs of an ascarid pass from the human intestine into the soil, where there is sufficient moisture and air to support their development. Larvae develop in the eggs in two-three weeks.

From poorly washed vegetables, or from dirty hands the eggs containing larvae may enter the mouth and then the intestine of a human. The larvae hatch out of the eggs, bore into the intestine's walls and enter the blood, which carries them into the lungs. Then, they pass through the pharynx together with the sputum and again enter the intestine, where they grow up into adult worms and begin to reproduce.

HARM OF ASCARIDS. Ascarids intoxicate a human by poisonous substances, causing intestinal disorders and pains. Many medicinal means for eliminating ascarids are available, which should be taken only as prescribed and under the supervision of a physician.

? 1. What specific features in the structure of an ascarid make it different from a flatworm?

△ 2. How can one protect oneself against ascarids?

2.8 The Variety of Parasitic Worms and Their Control

FLAT AND ROUNDWORMS – PARASITES OF HUMANS AND ANIMALS. There are about 10 000 species of flat and round parasitic worms beside the liver fluke, the beef tapeworm and human ascarid.

Parasitic worms inhabit the organism of wild and domestic animals, and some find their habitat in the human organism. They live in the organism of the host, feed at its expense, injure its organs, and cause intoxication.

The Siberian liver fluke, which is dangerous in the class of flukes, occurs in the liver of cats, dogs, and some other animals and humans. Infection occurs from eating raw frozen fish.

The Schistosoma fluke is common to the tropical countries of Africa, Asia, and South America. This fluke parasitizes in the blood of man and of some domestic animals. Tailed larvae of Schistosoma mature in red snails are called Biomphalaria. Having entered the water from the snail's body, the larva can bore through the skin of a swimming or working person. At the place where the larvae have entered the body, the skin is red and intense itching is experienced. Once through the skin, the larvae enter large blood vessels where they live. These parasites cause a very serious illness – Schistosomiasis, which is very difficult to treat. Today, there are approximately 200 million victims of this parasite.

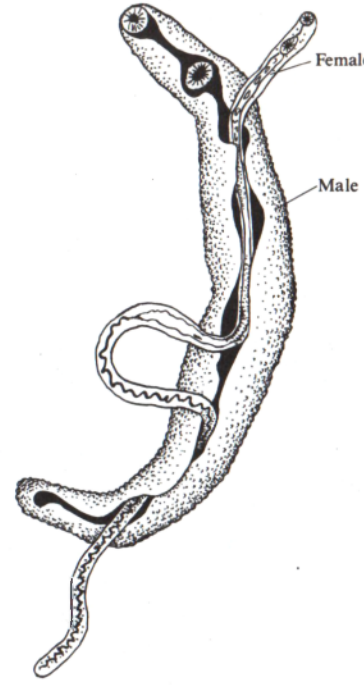


Fig. 30. Schistosoma

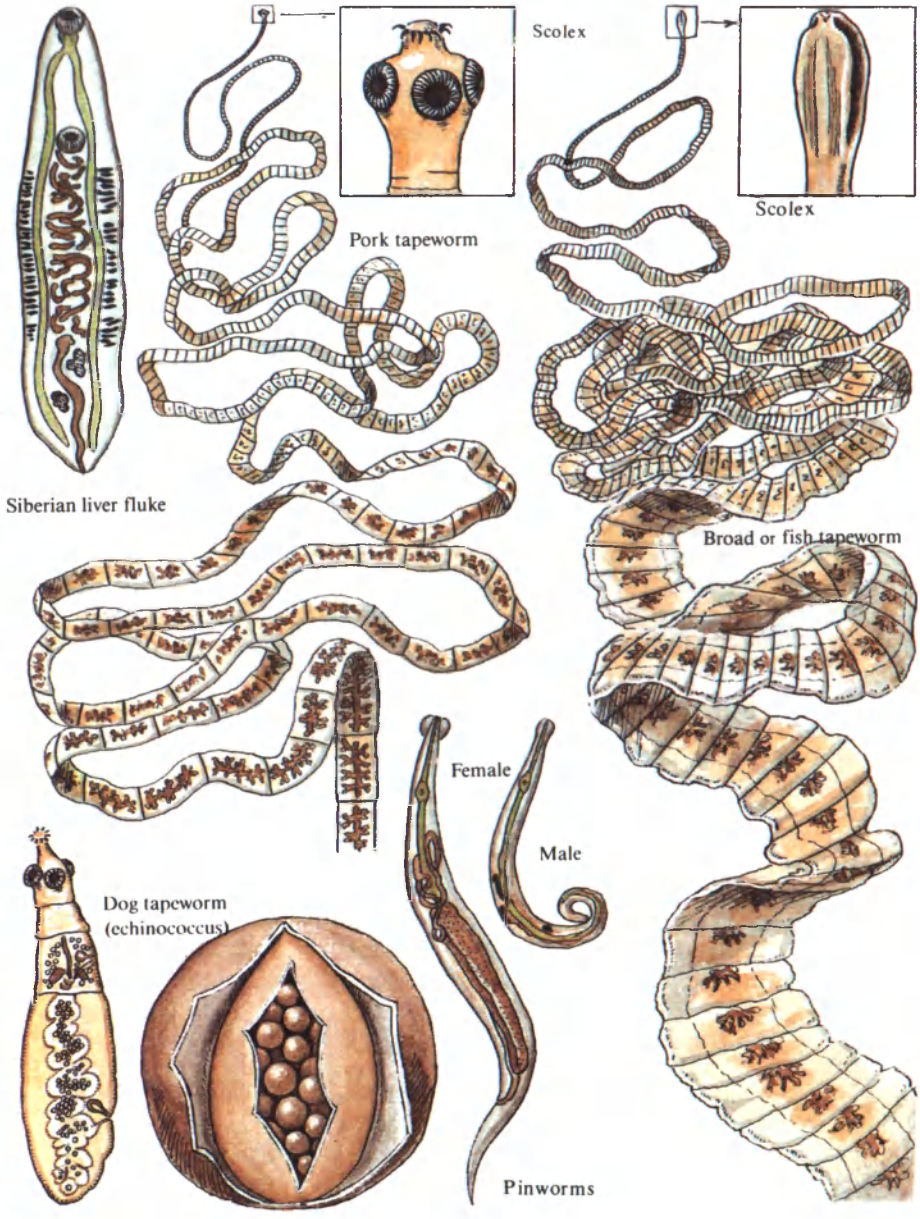


Fig. 31. Parasitic worms

To avoid becoming infested by these parasites, one should not swim in small, poorly flowing and well warmed waters which are inhabited by snails, the hosts of Schistosoma larvae. When working in such bodies of water, i.e. washing clothes or irrigating rice fields, it is mandatory to wear protective clothing (rubber boots and gloves) which prevent the larvae of this parasite from penetrating the skin.

The broad fish tapeworm of the class of tapeworms is found quite often in humans. Men get this worm from consuming underfried fish or raw pike roe. A human is infected by the pork tapeworm when eating underfried or undercooked pork meat containing cysticerci (vesicular larvae).

The vesicular stage of the dog tapeworm (echinococcus) is distinguished by its large size (up to the size of a child's head), because a lot of little scolices are formed in the vesicle. The bladder of a dog tapeworm develop in various internal organs of horned stock, and sometimes in humans.

When a dog consumes meat with echinococcus, adult tapeworms begin to develop from the heads of the parasite in the dog's organism. The eggs of the parasite are excreted and may stick to the dog's fur.

When petting such a dog, a human may bring the eggs into his mouth and become invaded with this dangerous parasite.

The pinworm is five-ten mm long and inhabits the human intestine, more often in children. The female of a pinworm crawls out of the anus and lays eggs on the skin around the anal region of the host, causing itching. When scratching the itching spot, the eggs stick under the nails and a human may reinfect himself.

ADAPTATIONS OF PARASITES. Characteristic specific features have developed in many worms as a result of their parasitic mode of life: organs of attachment, namely, suckers and hooks. Parasitic worms are characterized by great fecundity, because the majority of eggs disperse and perish without getting into a new host.

CONTROL OF PARASITIC WORMS. Many parasitic worms cause serious illnesses in humans and domestic animals. Hence, a widespread struggle is carried out against flukes, tapeworms, and other parasites. The success of this struggle in our country is made possible by the achievements of scientists-parasitologists.

Significant scientific and practical results have been obtained by Academician Konstantin Ivanovich Skryabin and his followers, who proposed many methods for fighting parasitic worms and elaborated measures to prevent infestation.

It is very important to study the development of parasitic worms in order to establish methods for exterminating them. Purification of drinking water, sanitary control at slaughter houses, correct cooking, observance of personal hygiene are most important in the control of parasitic worms.

All schoolchildren are examined at schools for eggs of parasitic worms in order to expel the parasites, if any are found. To protect oneself against them, one should wash one's hands very thoroughly before food, after earthwork, attending to animals, visiting a toilet. One should not eat unwashed vegetables and fruit, underfried or undercooked meat and fish.

1. What is the difference between flat parasitic worms (for example, the liver fluke and the beef tapeworm) and freely living worms (the white planarian)?
2. What are the main accessories of the flat and roundworms to the parasitic mode of life?
3. What are the main measures of personal hygiene which protect against parasitic worms?

Phylum: Annelida

Class: Oligochaeta

2.9 Earthworm

MODE OF LIFE AND EXTERNAL STRUCTURE. Earthworms (!) spend their life in burrows, digging them in the soil. They appear on the surface rarely, only at night, or after a rain. These worms are quite numerous in humus soils and near dung-hills. Earthworms do not occur in dry soil.

In summer the worms stay in the surface strata of the soil, and burrow holes down to two meters deep for the winter. These worms know very few enemies, owing to their concealed mode of life, but they are devoured underground by moles, while toads and birds feed on them on the surface.

An earthworm has a very long body (up to 10-15 cm), round in the cross section. It can contract and elongate. The main characteristic of all annelids are *circular bands*, that divide the earthworm's body into 100-180 segments. A small thickening, called the *clitellum*, is visible in the anterior third of the earthworm's body.

Thin, elastic and short bristles known as *setae* develop on the abdominal side of the worm. The bristles assist the worm in moving forward on the soil surface and particularly at burrowing. The presence of sparse bristles is

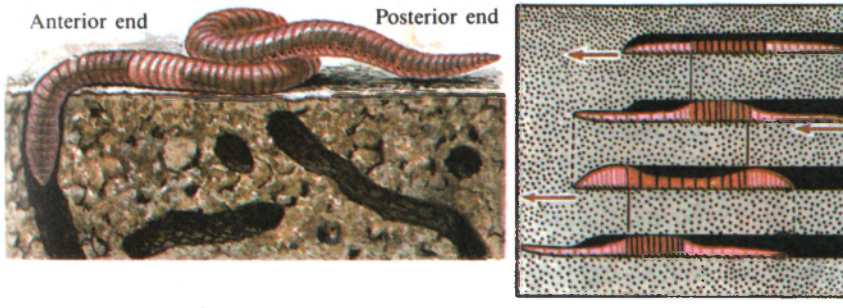


Fig. 32. Earthworm and its motion in soil

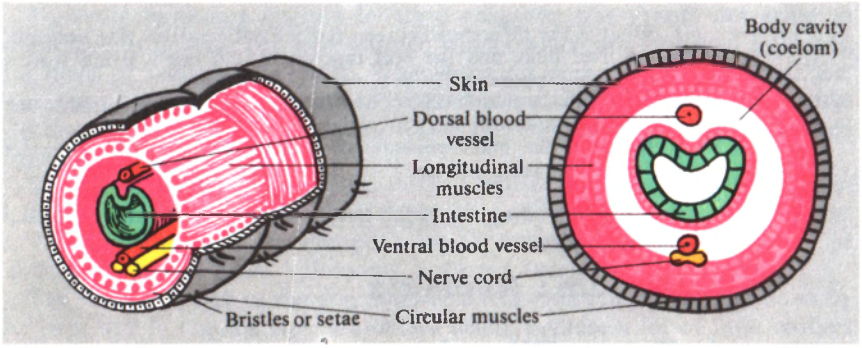


Fig. 33. Internal structure of an earthworm. Diagram

a specific feature of the entire class of oligochaetes. The earthworm has a red-brown coloration, and the abdominal side is lighter than the dorsal one.

TISSUES. The *skin* of the earthworm is formed by an external layer of cells. These cells protect the internal organs against the effect of the environment. In totality they form the *integumentary tissue*. *Tissue* is a group of cells of similar structure, performing a similar function in the organism. Beside the integumentary tissue, animals have also *muscular, nervous*, and other tissues.

MUSCULATURE. SKIN-MUSCULAR SAC. *Circular muscles* are arranged under a layer of integumentary tissue. When these muscles contract, the worm's body elongates. The longitudinal muscles are under the circular ones. Their activity causes contraction of the worm's body.

The alternating muscular activity is very important for burrowing. As a result of contraction of the circular muscles, the anterior end of the body becomes very thin and the worm advances it easily between the soil particles. Then the contraction of the longitudinal muscles thickens the anterior end of its body and moves the soil particles apart, thereby forming a burrow.

The skin and the layer of muscles are in close contact with one another, together forming a *skin-muscular sac*, which is found also in flat and round worms. It plays an important role in contributing to motion.

BODY CAVITY. The skin-muscular sac of an earthworm surrounds a body cavity filled with a fluid, wherein the internal organs are located. Transversal septa divide the body cavity into compartments, whose number corresponds to the number of segments. The cells of the septa make up a third, central layer. It lines the entire body cavity of the earthworm: it wraps around the organs of the digestive system and the inside of the skin-muscular sac. This layer of cells is found in all multicellular animals beginning with worms.

DIGESTIVE ORGANS. An earthworm feeds on decaying plant matter, which it swallows with the earth. It can drag dropped off leaves into its burrow and swallow them in parts. The *mouth* of an earthworm is at the anterior end of the body. The food passes from the mouth through the *pharynx* into the *esophagus*. The posterior end of the esophagus swells up

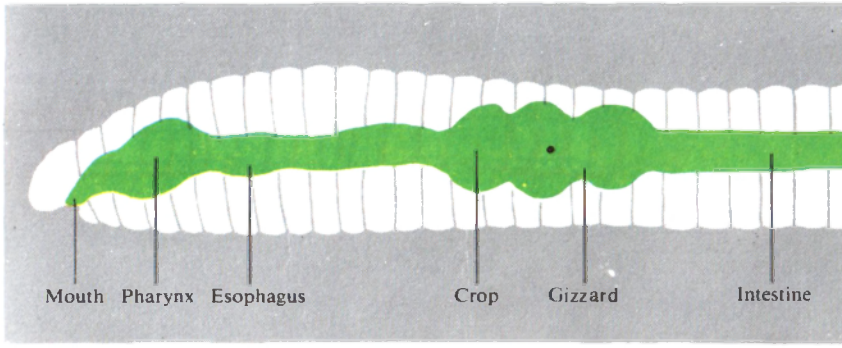


Fig. 34. Digestive system of an earthworm. Diagram

and forms a space for the food, namely, a *crop*. A small widened *gizzard* is joined to the crop. The walls of the gizzard have muscles that grind the food. An *intestine* runs from the gizzard to the terminal end of the body. The ground food is digested in the intestine under the effect of digestive juices, and the nutrients are absorbed. The undigested remains are excreted through the anus. The mouth, pharynx, esophagus, crop, gizzard, intestine are the organs that together form the *digestive system*.

? △ 1. Name what helps an earthworm adapt to its mode of life.
2. What tissues form the skin-muscular sac?

2.10 Earthworm (continued)

BLOOD CIRCULATION AND RESPIRATION. Unlike all the other animals considered earlier, an earthworm has a *circulatory system* consisting of *blood vessels* in which the blood flows. A *dorsal vessel* runs along the worm's body above the digestive organs, and a *ventral vessel* is located under the latter. A circular connecting vessel is located in each segment between these main vessels. Several thick-walled connecting vessels in the anterior part of the body perform the role of "hearts". They have muscles that contract regularly and cause motion of the blood in the dorsal vessel from the posterior end of the body to the anterior portion. The "hearts" pump the blood into the ventral vessel, in which it flows in the opposite direction to the posterior end of the body.

Finer vessels run from the main longitudinal and circular vessels to different parts of the worm's body, where they branch into very fine vessels that are called *capillaries*. The red blood of the worm never mixes with the colourless fluid in the body cavity. Hence, the circulatory system of an earthworm is *closed* as it does not communicate with the body cavity. The thick network of capillaries approaches the intestine, where the

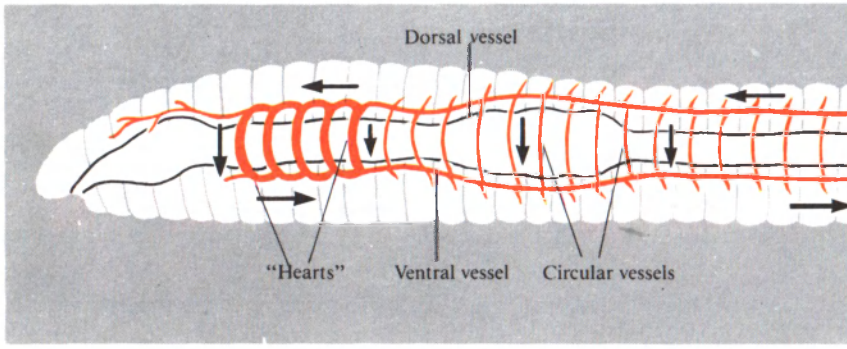


Fig. 35. Circulatory system of an earthworm. Diagram

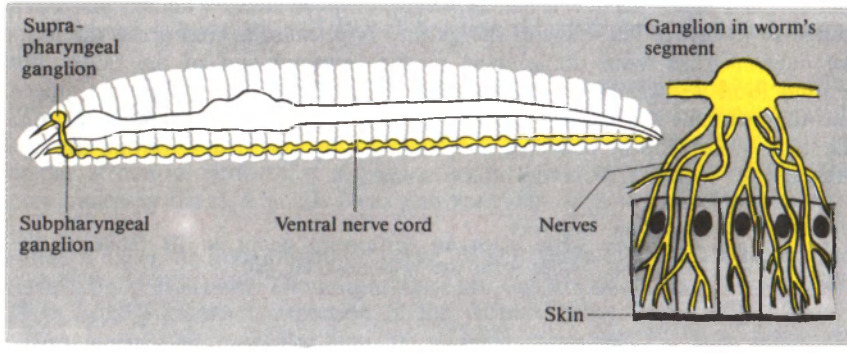


Fig. 36. Nervous system of an earthworm. Diagram

nutrients absorbed by the walls of the intestine pass into the blood, which carries them all over the body. The blood also carries oxygen, which worms receive from the air in the soil. When the soil is wet after a rain, the worms crawl out to breathe on the surface. Oxygen enters the worm's organism through the entire surface of the skin. It penetrates into the numerous capillaries of the circulatory system. The blood is enriched in the tissues with gaseous carbon dioxide, which is then expelled through the skin.

EXCRETION. Harmful liquid by-products of vital activity accumulate in the body cavity. Each segment of an earthworm contains a pair of *excretory organs* (nephridia), which are thin, looped, coiled tubes. One end of the tube is connected to the body cavity, while the other one opens externally. The harmful liquid substances are excreted through these tubes from the earthworm's organism.

NERVOUS SYSTEM. A small *ganglion* is arranged ventrally in each segment of the worm. All the ganglia are interconnected, forming a ventral *nerve cord*. A large *subpharyngeal ganglion* is located at the front of this cord under the pharynx, and the largest *suprapharyngeal* or *cerebral ganglion* is on

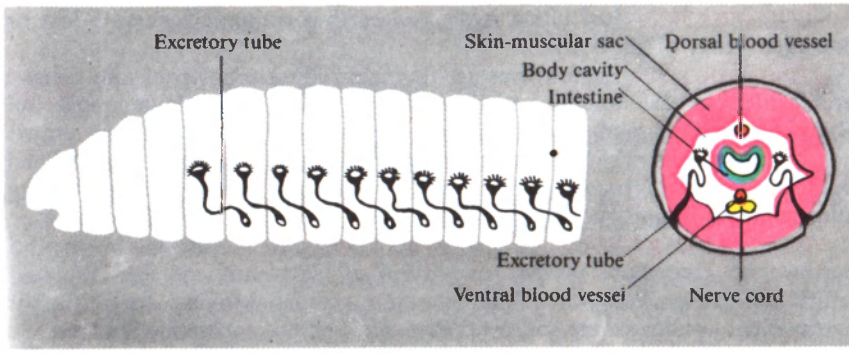


Fig. 37. Excretory system of an earthworm. Diagram

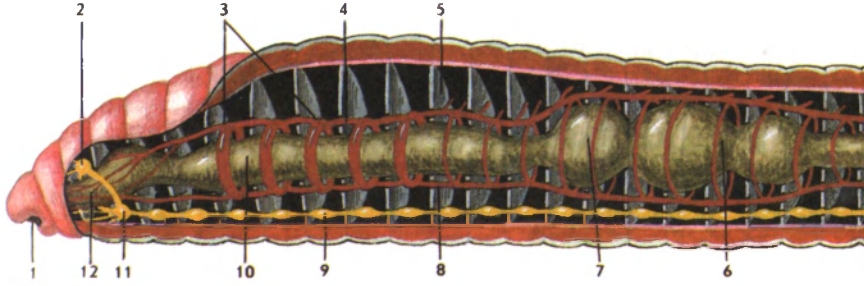


Fig. 38. Write down the names of the earthworm's organs in the given sequence

the anterior end of the pharynx. The suprapharyngeal and subpharyngeal ganglia are connected by a pair of circumpharyngeal connectives, extending from the ganglia and encircling the pharynx. Nerves extend from all the ganglia to various parts of the worm's body.

The worm has no special sense organs, but it reacts to a touch to its body, to the taste of food, discriminates light from darkness. The stimuli are perceived by the *sensory cells* of the skin, which are connected to the ganglia by means of nerves. There are very many sensory cells in the anterior part of the body, and the nerves run from the cells to the cerebral and subpharyngeal ganglia.

The reflexes of an earthworm are more complicated than those of coelenterates and flatworms. We know that a touch of a needle to any part of the body of a hydra or a planarian causes general contraction of the animal. Unlike the latter animals, when an earthworm is pricked with a needle, it bends to one or the other side, contracting only the anterior or posterior part of the body. The more complex nature of the reflexes of an earthworm results from the more complicated structure of its nervous system.

REGENERATION. Just like a hydra, an earthworm can regenerate lost or damaged parts of its body.

REPRODUCTION. Earthworms are hermaphrodites. The testes and ovaries are located in the anterior portion of the body. When laying eggs, an abundant amount of mucus is secreted by the clitellum. The worm crawls out of the mucus which holds the eggs. The mucus hardens rapidly and darkens, forming a *cocoon* with several eggs inside. Young worms develop after some time and they leave the cocoon.

ROLE OF EARTHWORMS IN SOIL FORMATION. When burrowing, earthworms contribute to the penetration of water and air into the soil, which is so necessary for the growing plants. Moving forward, the earthworms swallow some soil, let it pass through their intestine, and excrete it behind their bodies, disintegrating, mixing, and enriching the soil with humus. All this makes the soil favourable for the growth of plants. One earthworm can process about 0.5 g of soil per day. Their role is great in soil formation in fields and gardens where the number of earthworms is high. Thus, up to 4.5 million earthworms are found in one hectare of fields rich in humus in the Moscow district. They "plough" 450 tons of soil in 200 days! Experiments demonstrate that the plants grow poorly and the yield is low if there are no earthworms in the soil. Therefore, it is necessary to protect earthworms, because they are very useful animals.

? △

1. What is the importance of the earthworm's circulatory system?
2. What good do earthworms do?
3. Look at the diagram of the animal world evolution (inside front cover). Determine the place occupied by the classes of the phyla of flat, round and annelid worms.
4. Name the main features in the structure of worms of each phylum.

■

1. Take a glass jar with moist soil and several earthworms. Put a layer of sand on the top (about 1 cm thick). You'll find dark lumps on the sand on the next day, which is soil from the bottom layers that passed through the worm's intestine and was excreted on the sand surface.
2. Look at a living earthworm and draw it. Find the anterior and posterior ends of the body, the ventral and dorsal sides, the clitellum. Pay attention to the annelid structure of the worm's body.
3. Put an earthworm on a sheet of rough paper. Try to hear the weak rustling generated by the crawling worm when it touches the paper with its bristles. Put a finger on the ventral side of the worm and move your finger from the anterior to the posterior end of the animal and then back in the opposite direction. You will feel the bristles. When you finish this assignment, put the worm back into the jar with soil and wash your hands.

Class: Polychaeta

2.11 Marine Annelids

Various annelids live in the sea waters. Some of them burrow into the sand, others crawl around on the bottom. Let's analyze in detail one of these crawling worms, namely, a *nereid*. The nereid's body is divided into segments. The head is at the anterior end with several tentacles, two pairs of eyes, a mouth with a pair of jaws. Nereids have flat blade-like outgrowths on the lateral sides of the body segments. The blades carry bunches of numerous long setae (bristles), owing to which the entire class is called polychaeta (meaning "many setae"). The nereid moves around on the bottom owing to the rapid motion of these blades. When moving, the worm is supported against the bottom by the bunches of setae. The nereid feeds on algae and tiny animals, grabbing them with its sharp jaws.

A nereid, like an earthworm, breathes with the entire surface of its body, but like many other aquatic annelids, for example, a lugworm, the blades carry special respiration organs, namely, *gills*, that look like branching outgrowths of the integumentary tissue. The gills contain many capillary blood vessels, wherein the blood is enriched with oxygen from the air dissolved in the water, and the carbon dioxide is released into the water. Many aquatic fishes feed on nereids and other annelids.

Phylum: Mollusca

Class: Gastropoda

2.12 Pond Snail and Other Gastropod Mollusks

MODE OF LIFE AND EXTERNAL STRUCTURE OF A POND SNAIL. One can always find a large snail, namely, a pond snail in ponds, lakes and quiet backwaters on aquatic plants. The snail's body is contained in a spirally coiled shell, having a sharp apex, four-five

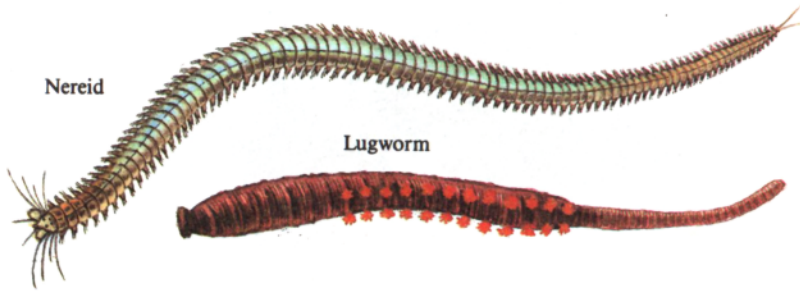


Fig. 39. Polychaete worms

whorls, and a large aperture. The shell serves to protect the soft mollusk's body, the muscles are attached to the shell's inside. The shell is made of lime, covered with a layer of a greenish-brown horny substance.

Three main parts can be distinguished in the body of a pond snail: a *trunk*, a *head*, and a *foot*, but there are no distinct borders between them. Only the head, the front part of the trunk and the foot can extend from the shell's aperture. The snail's foot is muscular. The mollusk moves when wave-like contractions run over its sole. The snail's foot is on the ventral side of the body.

The trunk repeats the shape of the shell, sticking tightly to its internal surface. It is covered on the outside with a fold of tissue called a *mantle*.

The anterior portion of the trunk turns into a head with a mouth on the underside of the body and two sensory tentacles on the lateral side. When the tentacles are touched, the mollusk rapidly retracts its head and foot into the shell. An eye is located near the base of each tentacle on the head.

NUTRITION. The snail feeds on aquatic plants. A muscular tongue in its pharynx is covered with solid small teeth. The snail sticks out its tongue occasionally and uses it as a grater to scrape off the soft parts of plants, which it swallows. The food passes through the pharynx and esophagus into the stomach and then into the intestine. The intestine bends like a loop inside the trunk and ends near the edge of the mantle by an anus. Unlike all other animals studied earlier, the snail has a digestive gland, namely, a *liver*, whose cells produce digestive juices. Thus, the digestive system of the pond snail is more complicated than that of an earthworm.

RESPIRATION. Despite the fact that the pond snail lives in water, it breathes oxygen from atmospheric air. To breathe, the snail surfaces and opens a round respiratory opening, pneumostome, on the right-hand side of its body at the edge of the shell. This opening leads to a special respiratory chamber of the mantle, namely, the *lung*. The walls of the lung contain a thick network of blood vessels, wherein the blood is enriched with oxygen, and carbon dioxide is released. The mollusk comes to the surface seven-nine times per hour to breathe.

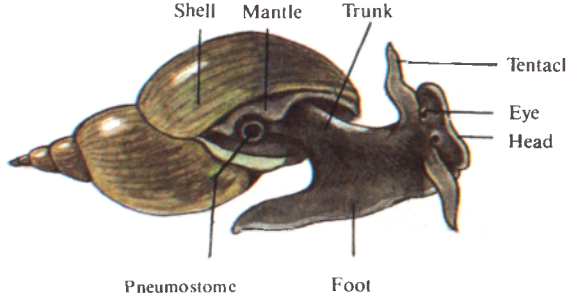


Fig. 40. Pond snail

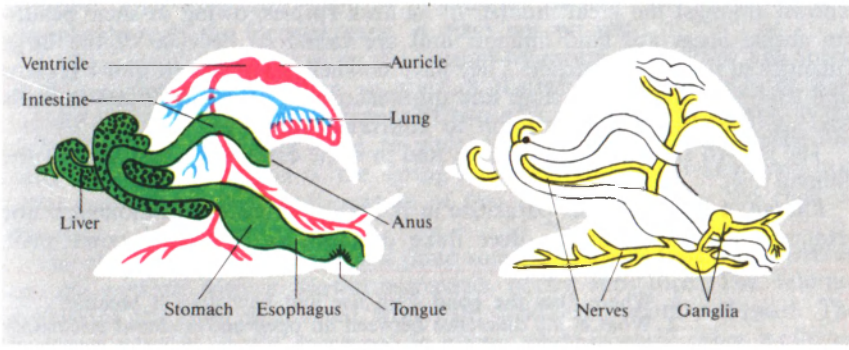


Fig. 41. Internal structure of a pond snail. Diagram

BLOOD CIRCULATION. The muscular heart near the lung is comprised of two chambers, namely, an auricle and a ventricle. Their walls contract alternately (20–30 times a minute), pumping the blood into the vessels. The large vessels turn into fine capillaries, wherefrom the blood discharges into the space between the organs. Thus, unlike annelid worms, the circulatory system of the mollusk is *not a closed one*, because it communicates with the body cavity and the blood does not flow all the time in the vessels. The blood is collected from the body cavity in a vessel near the lung, becomes enriched with oxygen, and enters the auricle. The pond snail's blood is colourless.

EXCRETION. A pond snail has one excretory organ, namely, a *kidney*. Its structure is quite complex, but it resembles in general the excretory organs of an earthworm.

NERVOUS SYSTEM. The main part of the snail's nervous system consists of an accumulation of ganglia near the pharynx, giving off nerves to all the organs of the mollusk.

REPRODUCTION. Pond snails are hermaphrodites. They lay numerous eggs encased in transparent mucous cords, which they attach to underwater plants. Young mollusks in a thin shell hatch out of the eggs.

MARINE AND TERRESTRIAL GASTROPODS. Marine gastropods are best

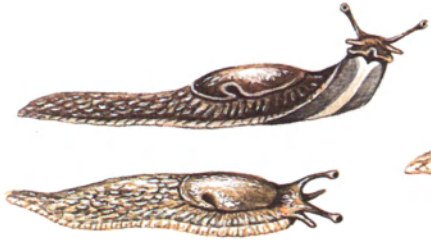


Fig. 42. Slugs

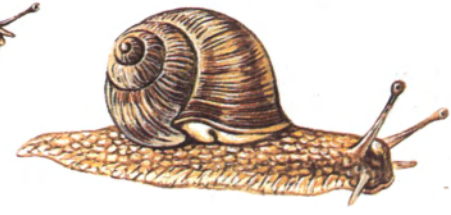


Fig. 43. Garden snail

known amongst the great number of mollusk species, owing to their beautiful shells. Slugs are land animals and are called so because of the large quantity of mucus they exude. They have no shell. Slugs live in moist regions and feed on plants. Many slugs feed on mushrooms, some are found in fields and gardens, doing certain harm to cultivated cultures.

The garden snail is widely known, and in some countries it is a part of the human diet.

Larvae of various flukes parasitize in the body of gastropod mollusks. For example, the larvae of the liver fluke develops in the small pond snail.

? △
1. Where does the pond snail live and how does it breathe?
2. What is the difference between an open and a closed circulatory system?
3. What harmful gastropods do you know? What harm do they do?

■ Place a pond snail in a glass jar with water. Watch how often it surfaces to breathe.

Class: Bivalvia

2.13 Fresh-Water Clam and Other Bivalve Mollusks

MODE OF LIFE AND EXTERNAL STRUCTURE OF A FRESH-WATER CLAM (ANODONTA). Another mollusk, namely, a fresh-water clam, occurs in the same water bodies as a pond snail. It dwells on the bottom, half-burrowed in the mud. The clam's oval shell is about 10 cm long. The front end of the shell is rounded, while the rear end is slightly pointed. The shell is comprised of two symmetrical valves: a right-hand one and a left-hand one. Both valves are joined dorsally by an elastic

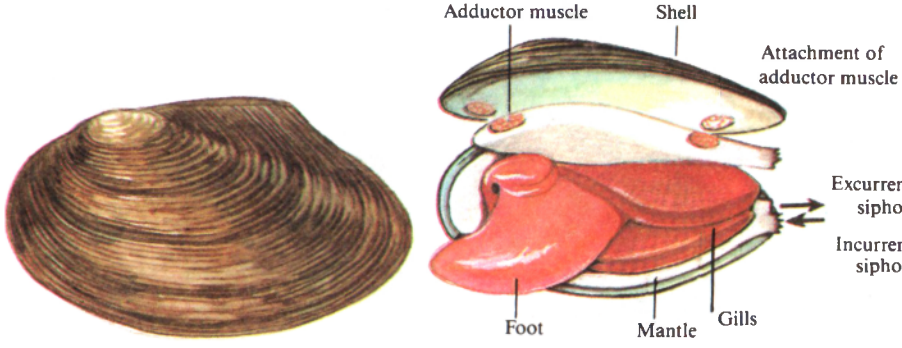


Fig. 44. Clam. Mollusk with shell opened (*right*)

ligament. The valves can open on the ventral side and the mollusk's foot extends through the forming gape. A clam has no head.

A clam can plow slowly along the bottom by means of its foot. The speed of its locomotion is 20-30 cm an hour. A disturbed clam retracts its foot rapidly and shuts the shell by means of two *adductor muscles* that run in the mollusk's body from one valve to another. When the muscles relax, the valves open by the action of the spring ligament. The fresh-water clam and other mollusks, whose shell consists of two valves, belong to the class of bivalvia.

The clam's shell, as the shell of a pond snail, is made of lime. It is covered on the outside with a brownish-greenish horny substance. The internal surface of the shell is covered with light irridescent mother-of-pearl. The nacreous layer is poorly developed in clams, while in some other mollusks, for example, fresh-water pearl shells and marine pearl oysters, it is much thicker. Pearly shells are used for making buttons and jewelry. The mother-of-pearl of a pearl oyster can encase a grain of sand that has entered the shell accidentally, and then a bright ball forms, which is a pearl.

The body of a clam is in the dorsal part of the shell, wherefrom two yellowish-pink skin folds of the mantle branch off, attaching tightly to the valves. Two gills are located immediately under the mantle on both sides.

NUTRITION. Bivalve mollusks feed differently than gastropods. The right-hand and left-hand mantle flaps in the rear part of a living bivalve press tightly to one another, but two openings, called *siphons*, remain between them. The gills and the internal sides of the mantle flaps are covered with cilia, which beat continuously and carry the water through the lower incurrent siphon. Various protozoa (flagellates, infusorians) and minute crustaceans are brought in with the water. The water current brings them to the clam's mouth, which is near the base of the animal's foot. Tentacles at the edges of the lower siphon form a sieve that prevents the entrance of large foreign particles.

The water is discharged through the upper or excurrent siphon. Thus, the mollusk does not search for food: it receives food continuously together with the water current.

The structure of the digestive system's organs in a clam is almost the same as in a pond snail.

RESPIRATION. The water current, which brings food to the clam, also provides for the respiration of the mollusk. The oxygen dissolved in the water enters the numerous blood vessels in the gills, and the carbon dioxide is released into the water.

The circulatory and excretory systems of the clam are similar in structure to those of a pond snail.

The nervous system has three pairs of ganglia. One pair is located above the esophagus, another is in the trunk, and the third is in the foot. The ganglia are interconnected by nerve fibers. A clam has no special sense organs.

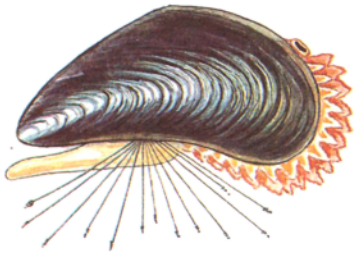


Fig. 45. Mussel

Fig. 46. Oyster

REPRODUCTION. Clams are *dioecious*. Males do not differ from females by appearance. Spermatozoa are discharged into the water and enter the female's body through the incurrent siphon. The eggs are fertilized in the female's body. Larvae with toothed valves develop from the egg. The larvae are discharged through the excurrent siphon and drop to the bottom. By flapping its valves, the larva can lift itself off the bottom and attach to the skin of a swimming fish. A tumor develops on the fish's body, wherein the mollusk continues to grow and develop. After some time, the mollusk tears open the host's skin and drops to the bottom.

Parasitizing on fish at the beginning of their life, the slow fresh-water clams are carried by the fish to new habitats.

MARINE BIVALVE MOLLUSKS. Many bivalve mollusks occur in the seas. Some of them, for example, mussels and oysters are a source of food for man and are even bred at a special "plantations" in the sea.

There are bivalve mollusks that can drill into wooden structures and even stone ones, damaging marine installations at sea ports. The greatest damage is done by the so-called ship worm, which drills into wood. This bivalve mollusk has a small shell on the anterior end of a worm-like body. Drilling passages, it destroys piles and other wooden structures.

The ship worm causes great damage to the wooden hulls of ships.

? 1. What is the structure of the respiratory organs of a fresh-water clam?

△ 2. What is the practical importance of bivalve mollusks?

■ Describe the major characteristics of the mollusk phylum. What is the main difference between the species in each of the two classes studied?

Find the mollusk phylum in the diagram of evolution (front inside cover).

Look at the shell of a clam. Find the spring ligament and the spots where the adductor muscles are attached.

Summer Assignment

Observation and Care of Living Animals

EARTHWORM. Take two sheets of window glass or acrylic plastic the size of a notebook. Bind them tightly on both sides with a string, placing three thin wood spacers (about 5 mm thick) in-between. Put humus soil between the glass sheets to 2/3 of its height and set this cage vertically. Now put two or three big earthworms into it. Observe how the worms dig into the soil and make burrows. Put several of last year's half-decayed wet leaves on the soil in the cage in the evening. In the morning see whether the worms found the food. Water the cage with the worms once a day with clean water. Draw in your notebook the passages made by the worms and then let them out into an orchard or a garden.

POND SNAIL. Put a pond snail in a one-liter jar with water from a pond or a river. Also put several branches of aquatic plants in the same jar. Place the jar in a light spot (but not in direct sunlight). Observe the movements of the pond snail. Count how many times it surfaces to breathe. A week later, when the walls of the jar will be covered with a green bloom of unicellular algae, observe how the pond snail feeds. After you have completed your observations, release the snail into its natural habitat.

GARDEN SPIDER. Find the hunting web of a garden spider or some other web-spinning spider. Draw its shape. Catch a fly and put it in the web. Observe the behaviour of the spider.

ANTS. Find an anthill in the forest and observe the activities of ants. Watch how the ants take the food into the anthill. Try to find the ant's paths around the anthill and draw their plan in your notebook.

BEE. Observe the work of bees on meadow flowers or garden plants. Pay attention to the pollen that sticks to the bee. Recall its importance for the plants.

BIRDS. Find a nest of a swallow, sparrow, pigeon, or some other bird. Don't approach the nest but watch it every day. How will you learn that the nestlings have hatched out? Count how many times an hour the parents feed the nestlings in the morning, afternoon and the evening. How do the nestlings react to the arrival of their parents? Set feed boxes for the birds in a park, orchard or garden, or on the balcony, if you live in a city. Put crushed sunflower seeds in the feed box, pieces of unsalted pork fat, bread crumbs. Observe which birds come to the feed boxes.

During an excursion to a forest, examine carefully old trees and try to find a hollow. Try to determine who lives there (a squirrel, woodpeckers, tomtits, starlings). What traces of animal activity can be found at a tree with hollows?

Be quiet in a forest, on a meadow, in the field, or near a water body. Don't frighten birds, nor pick flowers, don't break branches of trees or bushes. Safeguard the habitats of wild animals.

Observe domestic animals (animals, birds): how do they care for their offspring, what are their habits?

Formulate the main rules of caring for domestic animals. What work did you do if you participate in caring for agricultural animals?

Make collections. Collect empty shells of gastropods and bivalve mollusks, wash them in water, then dry and put them in a box on a layer of cotton. Put a slip of paper inside each shell, indicating the place and time of collection.

Using a botanical press, make a herbarium of leaves damaged by insects. Separate the bark from old stumps and find traces of beetle larvae activity on the internal side of the bark. Dry the pieces of bark.

Photography. Make an album of photographs of domestic animals.

Phylum: Arthropoda

Class: Crustacea

2.14 Mode of Life and External Structure of a Crayfish

A crayfish, a typical representative of the class Crustacea, occurs in pure fresh water, for example, in rivers, brooks, and lakes. Crayfish hide in the daytime under stones or in burrows in the bottom or near the banks under the roots of trees. They leave their shelters at night in search of food. Crayfish are omnivorous. They feed on vegetation and animals, living or dead prey. Crayfish sense the smell of food from afar, especially if the dead bodies of frogs, fishes, and other animals have started to putrefy.

A crayfish, like all arthropods, has a solid cuticle that is made of an organic substance, namely, *chitin* mingled with lime salts. The light but solid chitinous cuticle protects the soft parts of the animal. Furthermore, it serves as an *exoskeleton*, because the muscles are attached to it on the inside. The solid cuticle of the crayfish is greenish-brown in colour. This protective coloration makes the animal invisible against the dark background of the bottom. The pigment in the crayfish's covering is destroyed when the crayfish is cooked, and its colour changes: the crayfish turns red.

The body of a crayfish is divided into two distinct parts: the massive *cephalothorax* and the flatter segmented *abdomen.*

The cephalothorax consists of two parts: the anterior (head) and the posterior (thoracic) regions that are fused together in such a way that they are immobile. A curved furrow, a seam, is clearly visible at the spots of the joint. The head section has a pointed extension, called rostrum, at the anterior end. Eyes on mobile stalks are located on the sides of the rostrum and two pairs of thin and very mobile antennae stick out ahead of the animal. One pair of antennae is short, and the other is long. These are the organs of taction and smell.

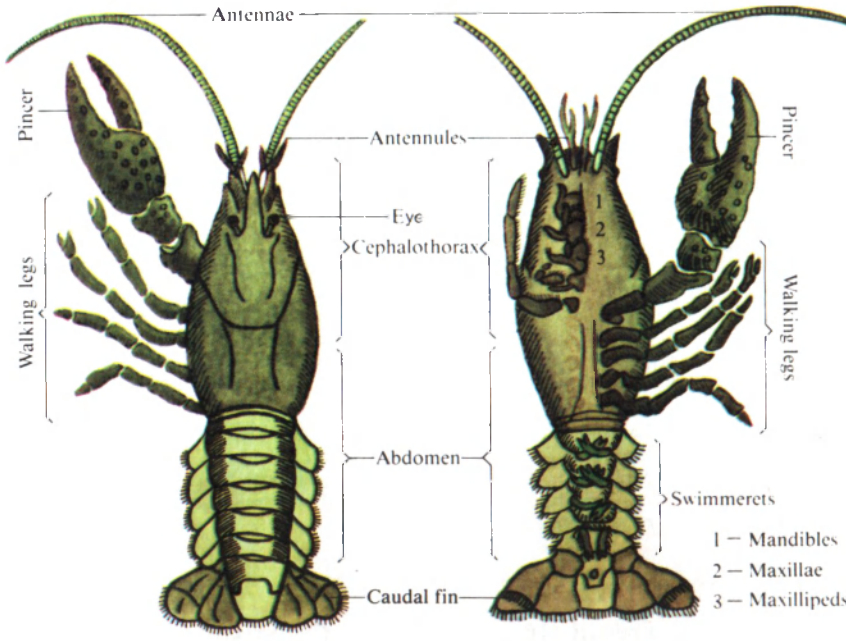


Fig. 47. Crayfish. Diagram

Six pairs of modified appendages, which are mouthparts, are on the sides of the mouth. The anterior pair is called *mandibles*, the second and third pairs are *maxillae*, and then follow three pairs of *maxillipeds*. The crayfish uses the pincers to grasp the prey, tear it into pieces, and bring it to the mouth. The crayfish uses its maxillipeds to hold the food, and with its mandibles and maxillae grinds it.

A crayfish has five pairs of segmented *walking legs* (hence, the name of the phylum – Arthropoda). The first pair of legs is the biggest one with well-developed *pincers*. These are organs of defense, offense, and are used also for grasping food. The next four pairs of legs are shorter, thinner, and are used for walking.

The abdomen comprises six mobile jointed segments and ends with a five-paddled *caudal fin*. Four pairs of short *swimmerets* are seen on the underside of the abdomen. The crayfish uses the walking legs to move along the bottom with its head forward. It swims with its tail part forward, curling its abdomen and propelling itself through the water with the five-paddled caudal fin.

Female crayfish differ externally from males. The abdomen in females is narrower than the cephalothorax. The female lays eggs at the end of the winter. The eggs attach to the mother's swimmerets. This is the place where the eggs develop. Young crayfish hatch out of the eggs at the beginning of the

summer. They stay for the first 10–12 days on the underside of the mother's abdomen, and then they start to live independently.

The chitinous cuticle enlarges with difficulty, therefore young crayfish grow irregularly. The old cuticle becomes too tight periodically for the growing animal. It separates from the body and a new shell forms within it. *Molting* occurs: the old cuticle splits, and the crayfish withdraws its body, already enclosed in soft and colourless chitin. The crayfish grows rapidly, and the chitin is impregnated with lime and hardens quickly. Then the growth of the animal stops until another molting takes place.

? △
1. What is the purpose of the chitinous cuticle?
2. Name the parts of the crayfish's body as shown in Figure 47.
3. What is the significance of molting in the life of arthropods?
4. Give titles to the different paragraphs in the text.

■ Dissect the chitinous skeleton of a crayfish. Glue the cephalothorax, abdominal segments and five-pedalled caudal fin to a piece of cardboard. Glue on their sides in the proper sequence the mouthparts, walking legs and swimmerets. Label all the parts of the skeleton that you know.

2.15 Internal Structure of a Crayfish

DIGESTIVE SYSTEM. The food passes through the pharynx and short esophagus into the stomach. The latter is comprised of two compartments. The food is ground finely in the big compartment by chitinous teeth. The smaller compartment consists of two plates with setae, that form a straining apparatus, and the triturated food is filtered through it, as if passing through a strainer. The triturated food enters the *intestine* and then the *digestive gland* or "liver", wherein it is digested by digestive juices. The nutrients are absorbed through the walls of the gland. The undigested remains pass on into the intestine and out of the anal opening near the middle paddle of the caudal fin.

Besides grinding teeth, white round lime concretions, called the "millstones" or gastrolithes, are found in spring and summer on the walls of the crayfish's stomach. The crayfish needs them to impregnate new soft chitinous cuticle after molting.

CIRCULATORY AND RESPIRATORY SYSTEMS. A heart, shaped like a whitish pentagonal sac, is on the dorsal side of the cephalothorax under the carapace. A series of blood vessels extend from the heart and their ends open freely into the body cavity. Thus, the circulatory system of a crayfish, like in the case of all arthropods, is an *open* one. Flowing in the spaces between the organs, the blood washes them and gives off oxygen. The blood then flows along the ventral side of the body to the gills, which are situated in the cephalothorax and are outgrowths of the skin chitinous cuticle. The surrounding water flows over them continuously. The oxygen dissolved in

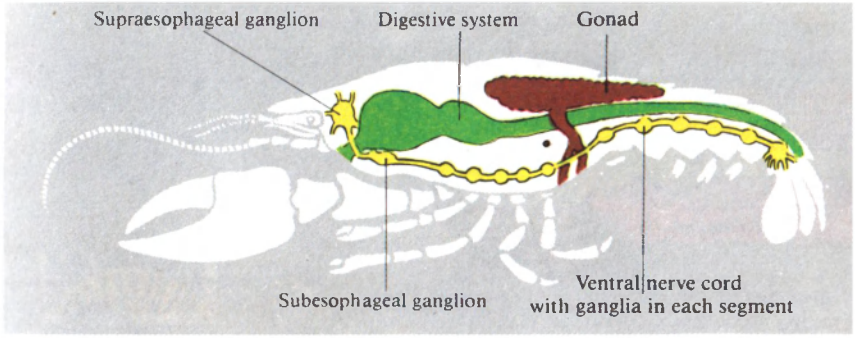


Fig. 48. Digestive, nervous and reproductive systems of a crayfish. Diagram

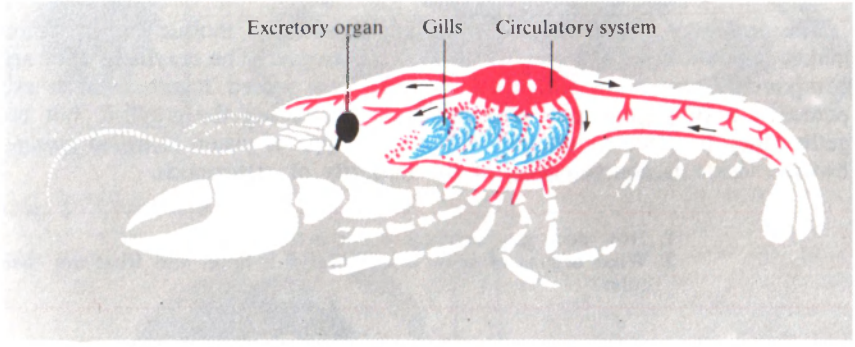


Fig. 49. Circulatory, respiratory and excretory systems of a crayfish. Diagram

the water passes through the gills into the blood, while the carbon dioxide accumulating in the blood is released through the gills. Thus, respiratory metabolism occurs. The oxygenated blood flows into the heart through openings therein.

A *pair of green glands* represents the excretory organs of a crayfish. Each gland has an excretory duct opening to the outside at the base of the antennae. Harmful by-products of vital activity that are dissolved in the blood are excreted from the crayfish's organism through the green glands.

NERVOUS SYSTEM AND SENSE ORGANS. As in the earthworm, the nervous system of a crayfish comprises a circumpharyngeal nerve ring and a ventral nerve cord. The crayfish's ganglia are more developed, especially the supraoesophageal and suboesophageal ones. Nerves run from the supraoesophageal ganglion to the eyes and the antennae, from the suboesophageal one to the mouthparts, and from the ventral nerve cord to the internal organs and the extremities.

The long antennae of a crayfish serve as *tactile organs*. The animal uses them to feel surrounding objects. The statocysts are at the base of the antennules.

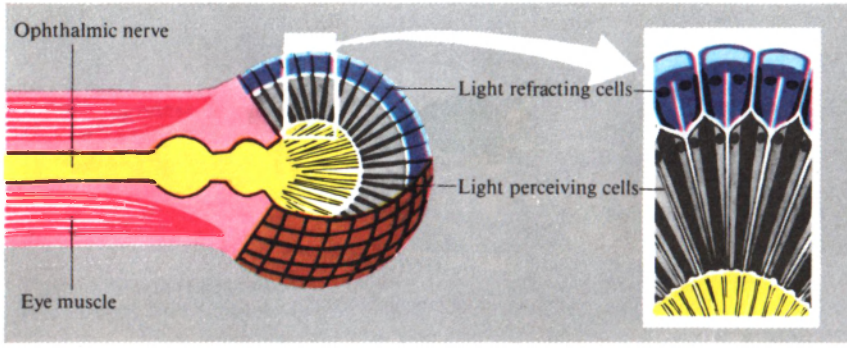


Fig. 50. Structure of a crayfish's eye. Diagram

The *organs of vision*, bulging eyes, are located on mobile stalks, which makes it possible for the crayfish to look all around. The crayfish's eyes are compound, comprising individual eyes that are joined together. Each eye perceives only a small part of the space surrounding the crayfish, but together they perceive an integral image. This type of vision is called *mosaic*. Mosaic vision is characteristic of the majority of arthropods.

? 1. How does gas exchange occur in crayfish?
△ 2. What organs of sense does a crayfish have, and what are their roles?

2.16 Freshwater, Marine, and Terrestrial Crustaceans

About one million tons of crayfish, as well as common shrimps and crabs, inhabiting the seas are caught worldwide annually. They are valued highly because of the tasty and nutritious meat of their pincers and abdomens. Crustaceans are cooked and canned.

Small Black Sea shrimps (about 7–8 cm long), living near the shores in algae thickets, are caught in the Black and Azov Seas. These shrimps have been brought to the Caspian and the Aral Seas, where they have reproduced. The seas in the eastern USSR are very rich in marketable crustaceans. Here is the habitat of the big grass shrimp (10–18 cm long) and of the tremendous king crabs (Paralithodes), whose extremities may span 1.5 m. The king crab is a predator. It feeds on polychaete worms, mollusks, crustaceans of other species. Shoals of these crabs wander for a greater part of the year along the sea bottom at a depth up to 250 m, and in spring they go to shallow waters to breed. The king crab lives up to 20 years, but it reaches marketable sizes only at the age of 8–10 years. Trade is limited because of the slow growth of

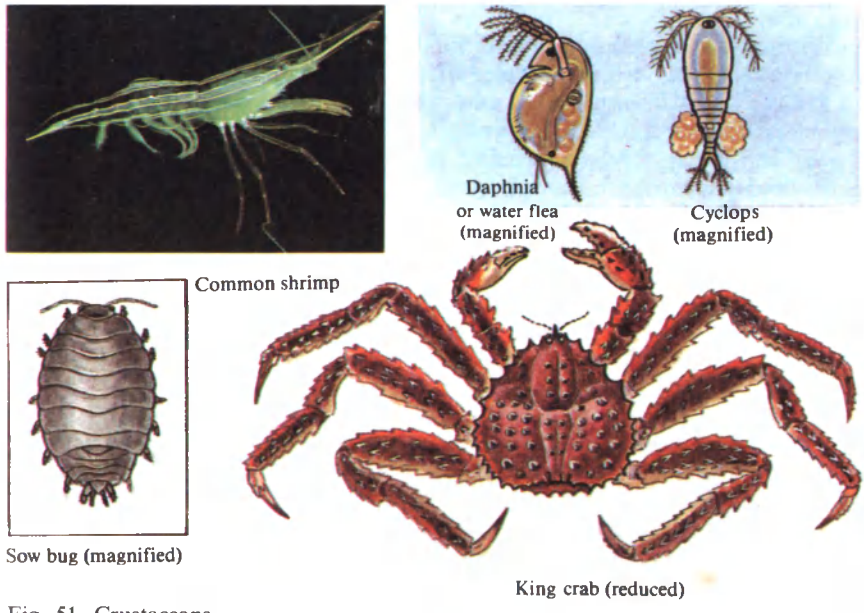


Fig. 51. Crustaceans

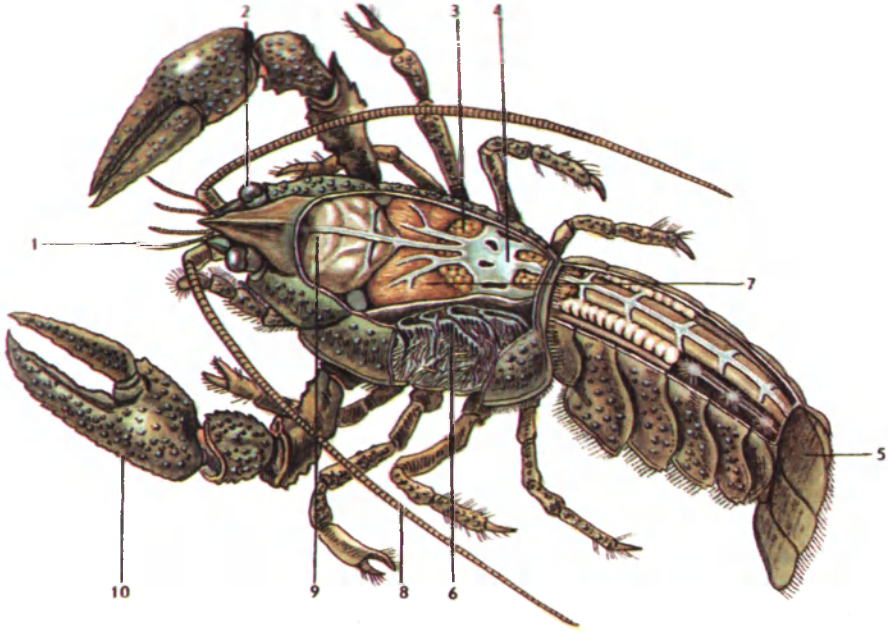


Fig. 52. Write down the names of the crayfish's organs in the given sequence

the animal. Crabs are caught in our country according to laws of environmental protection and utilization of the animal world, and with strict observance of the dates and rules of catching.

Various small crustaceans, that reproduce sometimes in very great numbers, inhabit seas and freshwater bodies. They serve as food for fry and the young of many fishes. Valuable marketable fishes, as herrings, feed on them and they are consumed even by animals of enormous sizes, for example, baleen whales. Tiny crustaceans, cyclops and daphnia, are bred at pond fishing farms to feed fry.

Large crabs leading a terrestrial mode of life occur in tropical countries. They dig deep burrows to hide when it is hot in the daytime, and surface at sunset in search of food. Once a year terrestrial crabs go into the sea to reproduce since their larvae develop in water.

? 1. What crustaceans are of marketable importance?
△ 2. What is the role of small crustaceans in the life of a water body?

Class: Arachnida

2.17 Structure and Mode of Life of a Garden Spider

EXTERNAL STRUCTURE. Arachnids are terrestrial animals, the structure of their body is adapted to life on land. The garden spider is a typical representative of the class of arachnids. Its body is clearly divided into a cephalothorax and an abdomen. The organs of sight, four pairs of simple eyes, the mouthparts and legs are located on the cephalothorax. The first pair of mouthparts, the *chelicerae* or upper jaws, have sharp fangs bent downward. The outlet ducts of *poison glands* open near the end of the fangs. The spider uses its jaws for attack, for killing its prey, and for defense. A second pair of mouthparts, *pedipalps*, are at the base of the jaws. They look like walking legs, but are shorter in length. The spider uses the pedipalps to feel and turn the prey while eating.

All arachnids have four pairs of *walking legs*. The spider's legs are long and covered with sense hairs. Claws are found on the terminal segment of each leg.

The abdomen is larger than the cephalothorax. A light cross is visible on the dark background of the spider's dorsal side. All the segments of the abdomen are fused together. Three pairs of *spinnerets*, into which the *silk glands* open, occur near the posterior end of the abdomen. The substance secreted by these glands solidifies in air and turns into silk filaments. The spider joins them into one common thread by means of comb claws located on the hind legs.

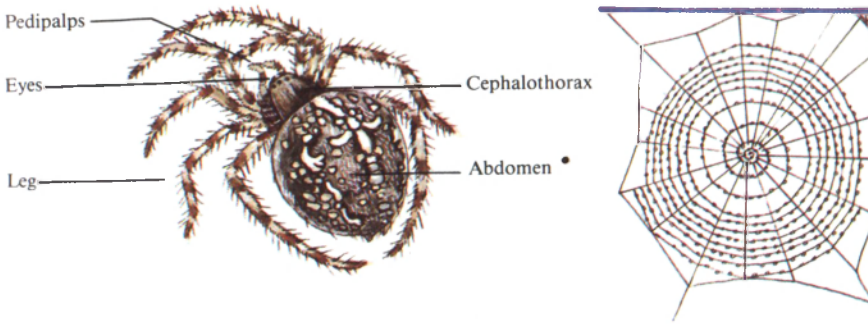


Fig. 53. Garden spider and its hunting web

HUNTING WEB. The female garden spider constructs a large hunting web of the silk thread, stretching the web vertically between the branches of bushes, near fences, and in other places. First a polygonal frame is made of thick unsticky threads converging in the centre. The spider adds a long, thin and very sticky thread to this base, following a spiral line.

HUNTING. The spider usually waits for its prey, lingering near the web in a concealed nest which is made of the spider's thread. A signalling thread extends from the centre of the web to the nest. When a fly, small butterfly, or some other flying insect is trapped in the web and begins to struggle for freedom, the signalling thread vibrates. The spider rushes out of its shelter and spins a thick web around the prey. It thrusts the fangs of its upper jaws into the prey and injects poison into it. Then the spider leaves the prey for some time and hides in its shelter.

NUTRITION. The secretion of the poison glands kills the prey. The digestive juices are regurgitated from the mouth. The spider returns an hour later and sucks the partially digested fluid content of the prey, leaving only the chitinous covering. A spider is unable to eat hard food. Thus, preliminary digestion of the food occurs outside the spider's organism.

RESPIRATION. A pair of lung sacs, communicating with the environment, is located in anterior part of the abdomen. These lungs for the peculiarity of their structure are called *book lungs*. Their walls form numerous sheet folds, wherein the blood circulates. The blood is enriched with oxygen from the air available between the folds. Besides book lungs, a spider has two bundles of breathing tubules, *tracheae*, that are contained in the spider's abdomen and open to the outside by a common *breathing opening*.

The circulatory system of a spider is basically the same as in a crayfish.

REPRODUCTION. A female garden spider is larger than a male one. In autumn it lays eggs in a cocoon, which is spun of thin silky thread. The cocoon is spun in various secluded corners: under the bark of stumps, under stones. The female garden spider dies at the approach of winter, and the eggs spend the winter in the warm cocoon. Young spiders hatch out in spring.

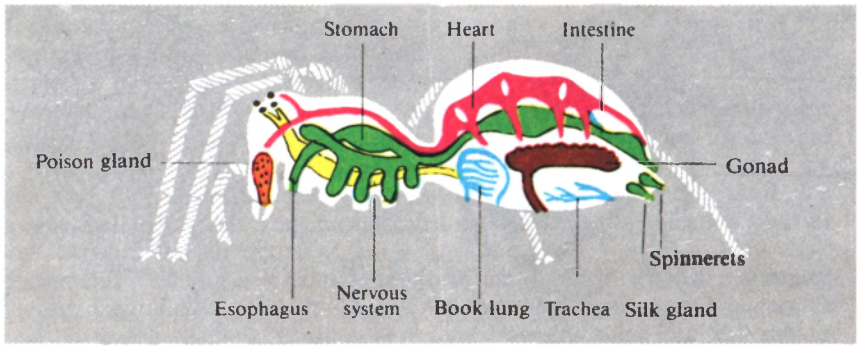


Fig. 54. Internal structure of a spider. Diagram

The bird-eating spider, whose body reaches 10 cm, inhabits tropical countries. It feeds not only on various insects, but can attack small birds as well.

Many spiders do not build nests or webs. These are wandering predators. They either wander in search of prey or sit immobile in ambush and jump on insects which may crawl by. These are called "wolf spiders".

SCORPIONS. These spider-like arthropods have a highly segmented body. An abdomen with broad front segments is jointed to the cephalothorax. The hind segments of the abdomen are narrow and form a very flexible posterior section which ends in a sharp curved sting. A duct from a poison gland opens into this sting. A scorpion, like a spider, has two pairs of mouth organs. It also has especially well developed pedipalps which resemble the claws of a crayfish.

Scorpions are nocturnal. During the day they hide under rocks, in cracks and crevices of the soil, and come out at night to hunt. They grasp their prey – various arthropods and primarily spiders – with their pincers. The scorpion then lifts its prey above its cephalothorax and kills it with its sting. Then it tears apart and swallows its prey in pieces.

The venom of a scorpion is fatal for small animals and dangerous to man. Scorpions inhabit warm regions.

? △

1. What subdivisions of the body can be discriminated in a garden spider?
2. How many legs does a garden spider have?
3. What is the design of the hunting web? (Use the materials of your summer observations in your answer.)
4. What specific features in the structure and behaviour of a garden spider are associated with its terrestrial mode of life, and which ones are independent of it and are characteristic of aquatic and terrestrial arthropods?

2.18 Mites (Ticks)

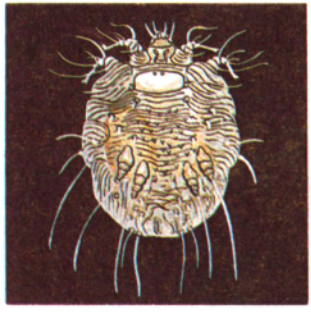
Mites are tiny creatures, sometimes microscopic in size. It is impossible to distinguish their cephalothorax and abdomen, because the segments of their body fuse into a whole. Many species of mites are pests of cultivated plants, and are parasites of animals and man.

The microscopically small red spider mite settles on the leaves of cotton or other valuable cultivated crops. It reduces the yield of cotton, and often destroys completely the infected plants. Some mites settle in grain, flour, and reproduce there in large numbers, thereby making the products inedible. The flour mite eats out the germ in the grain of the future plant.

Reproduction of the flour mite is prevented by thorough cleaning of the rooms where grain and flour are stored, also by using thoroughly washed sacks, and by maintaining dryness in the rooms.

The microscopically small itch mite causes itching and agonizing pain. Settling on a human, it sticks to the tender parts of the skin (usually between the fingers, or at the elbow bend) and bores into its upper layer. The mite gnaws a passage, causing violent itching, and lays eggs. The hatching mites come to the surface of the skin and gnaw new passages. A patient afflicted with itch mites can easily transmit mites to healthy humans by handshaking. Clean hands prevent the transmission of this disease.

Taiga ticks may be found occasionally, sticking or crawling under one's clothes after staying for some time in the woods or on a pasture in spring or in summer. They occur also on the bodies of cattle and dogs. Sitting on the tips of grass blades and extending its anterior pair of legs upward, the tick is on the watch for its hosts. It sticks so tightly to the fur of animals or to the clothes of a man, that it is difficult to shake it off. When it reaches the host's body, it pierces the skin with its mouthparts and begins to suck the blood, increasing greatly in size. A hungry female taiga tick, being only about 4 mm long, increases its length up to 10–11 mm after feeding. Having sucked its fill, the tick drops to the ground. The female then lays several thousand eggs. The hatching larvae crawl away and attack small animals: mice, birds, lizards. A tick changes its hosts three times during its life cycle.



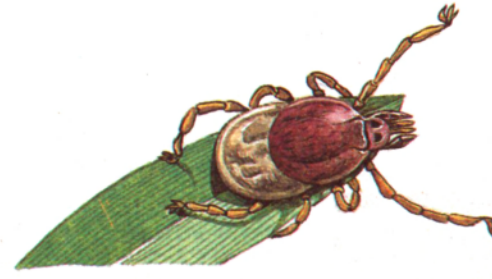


Fig. 55. Itch mite (strongly magnified). Pasture mite (magnified)

A taiga tick is a very dangerous parasite: when sucking blood, it can infect a human with encephalitis, a severe disease of the nervous system. The pathogene of encephalitis is in the body of various wild animals under natural conditions (for example, squirrels or rabbits). If a taiga tick attacks a man, having first sucked the blood of an infected animal, the man is infected with encephalitis. The cause of the disease has been a mystery for a long time. The role of ticks in transmitting encephalitis from wild animals to humans was discovered in the late 30s owing to the selfless work of a group of Soviet scientists under the guidance of Academician Yevgeny Nikanorovich Pavlovsky, a zoologist, and Academician Lev Aleksandrovich Zilber, a microbiologist.

To avoid infection with encephalitis, it is necessary to administer prophylactic inoculations, and after being in the woods, to change one's clothes and examine thoroughly the clothes and the surface of the skin. If any ticks are found, they should be exterminated.

? What are the main ways to protect oneself from ticks and to fight against them?

Class: Insecta

2.19 External Structure of a Cockchafer

OUTWARD APPEARANCE AND SUBDIVISIONS OF THE BODY. Everyone has certainly seen in spring and in early summer quite big (2-2.5 cm long) light-brown beetles of cylindrical shape with characteristic white triangular spots on their sides. These are cockchafers, which are widespread in the USSR from the western borders to the Far East. If one takes a cockchafer in one's hands, it is possible to see its firm covering, which is a strong and very light external chitinous skeleton. The body of a cockchafer like that of any other insects, has three subdivisions: a *head*, a *thorax*, and an *abdomen*.

HEAD. The head of the beetle bears the mouthparts and the sense organs. An *upper lip* or *labrum* in the form of a transversal plate is in front. Behind the lip are two pairs of *jaws* (the upper ones – mandibles and the lower ones – maxillae), limiting the mouth opening on the sides. The *lower lip* or *labium* is beneath the mouth. A pair of *feelers* or *palpi*, serving as organs of tactile and taste functions, is located on the maxillae and on the lower lip.

A pair of compound (faceted) eyes is located on the sides of the beetle's head. Each eye contains several thousand simple eyes (ommatidia). A pair of antennae with several widened plates at the tip are arranged anterior to the eyes. The plates serve as an olfactory organ. They are more developed in a male cockchafer than in a female one. The head seems to be pressed into

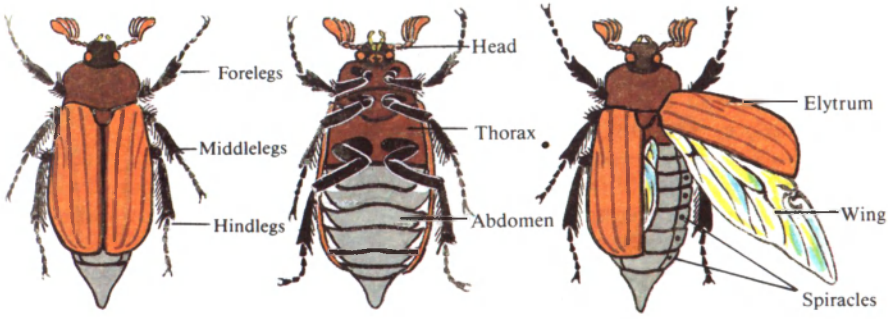


Fig. 56. Cockchafer. External structure. Diagram

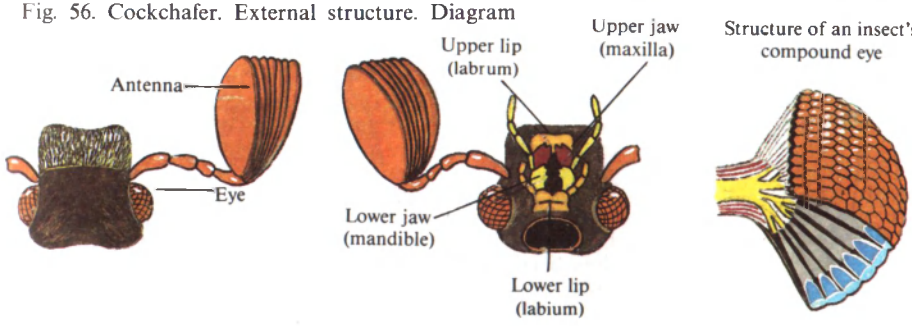


Fig. 57. Structure of a cockchafer head. Diagram

the anterior part of the thorax. The beetle can bend it, but it is unable to turn its head in different directions.

The thorax of the beetle is composed of three segments, and each one bears a pair of legs. Every insect has six legs. The middle and hind (posterior) segments bear *wings*.

Only the first segment of the thorax is seen on the dorsal side of the beetle, while the other two segments and almost the entire abdomen are covered by rigid *elytra*. They are modified forewings. The elytra protect the tender folded membranous wings and the dorsal side of the beetle's abdomen with its soft coverings. Rigid forewings are a characteristic indication of all beetles, which are called, therefore, coleopterans. When preparing to fly, the beetle lifts and draws aside the elytra, spreads the folded membranous wings, and takes off. In flight, the elytra are just as important for the beetle as the lifting planes for an aeroplane, while the wings perform as propellers.

The density of all four wings is the same in the case of butterflies, dragonflies, and bees. Many insects are perfect fliers. They cover long distances in flight in search of food, or to escape from enemies. Flying assists males to find females.

The majority of adult insects have wings, but fleas, lice, bed bugs, and some other ones do not. At some point, the ancestors of these insects were winged ones, but they lost their wings owing to their parasitic mode of life.

If a cockchafer is turned over with its abdomen upward, it is possible to see all three segments of the thorax, to which the legs are attached. The cockchafer uses its legs, which have sharp claws, to cling tightly to branches and leaves, and it is quite adroit at climbing them. It walks slowly on an even surface, waddling clumsily.

The abdomen of a cockchafer is fused immobile to the thorax. It consists of eight segments and is visible only from beneath, because its dorsal side is concealed by the elytra. Only the sharpened tip of the abdomen sticks out from beneath the elytra.

Spiracles, whose role will become clear when studying the internal structure of the insect, are visible at the edge of the dorsal side of the abdomen on each segment if the elytra are lifted and the thin semitransparent wings are spread apart.

? △

1. What are the divisions of an insect's body?
2. What are the similarities and the differences in the body structure of insects, arachnids and crustaceans? (Use Figures 47, 53, 56 in your answer.)
3. What is the importance of flight in the life of insects? Speak about it on the basis of your summer observations of flying insects, the specific features of their structure and mode of life.
4. How does a cockchafer fly?
5. What sense organs does a cockchafer have, where are they located, and what is their importance?
6. What is common in the structure of the eyes of a cockchafer and a crayfish? (Use Figures 50 and 57 in your answer.)

2.20 Internal Structure of a Cockchafer

The digestive system of insects is mainly the same as in crustaceans and arachnids, though there are differences.

A cockchafer feeds on young leaves of birch, oak, aspen, and other trees. It uses the sharpened ends of its maxillae to bite off small pieces of a leaf, and triturates the food by means of the serrated edges of the mandibles. Mouthparts of this structure, which are common also in other insects who bite their food, are called biting ones.

The swallowed food passes into the esophagus and then goes into a muscular gizzard. Insects feeding on solid or dense food usually have chitinous teeth in the gizzard to grind the food. The triturated food enters the gut wherein it is finally digested and the nutrients are absorbed. The undigested remains are excreted by way of the hindgut.

The structure of the mouthparts and other organs of the digestive system of insects depends on the food, which may be quite varied. Some insects feed on wood, dung, wool, the blood of warm-blooded animals and man, the nectar of flowers, other insects, and even such substances, that one would think quite inedible, for example, wax and chitin.

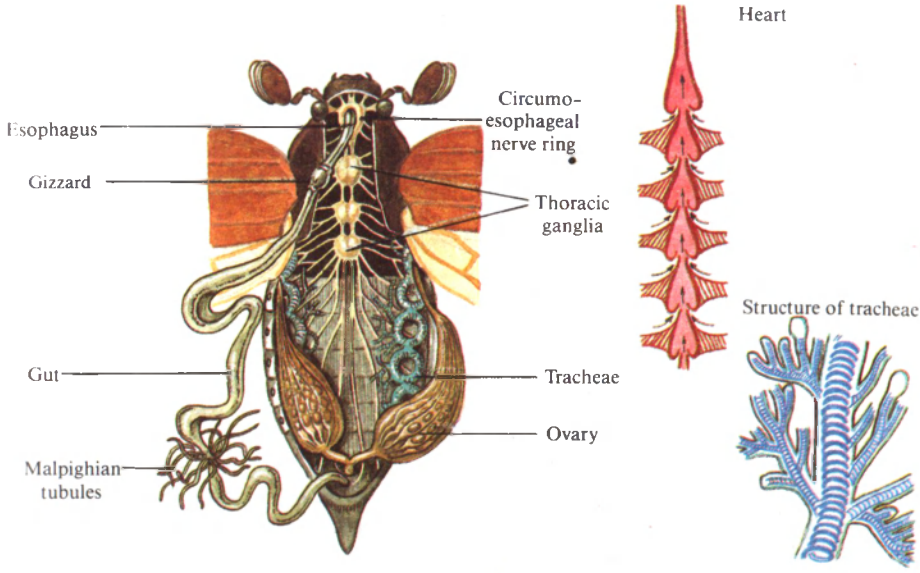


Fig. 58. Dissected cockchafer. Diagram

The circulatory system of an insect is very simple in its structure. The *heart* in the form of a tube with several valves inside is located dorsally in the abdomen, enabling the blood stream only in one direction, i.e. from the posterior to the anterior end. The sole blood vessel extends from the anterior of the heart and circulates blood to the head. The blood pumps into the body cavity, flows over the organs of the head, and then gradually circulates back to the anterior part of the body. The heart periodically expands under the effect of the muscles, and then the blood enters the heart tube through small paired openings called ostia, wherefrom it again flows to the head.

RESPIRATORY SYSTEM. Air enters the body of insects through spiracles, which were mentioned above (see Sec. 2.19). Chitinous breathing tubes, called tracheae, branch into the body. They branch many times in the body, twisting around all the internal organs and extending to the tips of the legs, antennae and palpi (or feelers). Observing some big insect, it is possible to see that its abdomen expands and contracts intermittently. When the muscles of the abdomen contract, the air is expelled from the tracheae and then the abdomen expands again, while fresh air enters the respiratory system.

The excretory organs of an insect are not joined into one system. A group of narrow long tubules extend to the posterior part of the alimentary canal. They are called *Malpighian tubules* after Marcello Malpighi, an Italian scientist, who lived in the 17th century and studied the structure of insects.

The walls of the Malpighian tubules remove liquid wastes of metabolism from the blood, which are then excreted from the organism through the hindgut.

All the internal organs of a beetle are covered or are encased totally in a whitish tissue, which is a *fatty body*. The cells of the fatty body also absorb wastes from the blood, though they are not eliminated from the organism but remain in the fatty body till the end of the insect's life. The fatty body serves not only as an excretory organ. Beside the waste products, it accumulates reserves of nutrients, mainly fat. The eggs develop and mature on account of the nutrients in the fatty body.

NERVOUS SYSTEM AND SENSE ORGANS. The nervous system consists of a circumoesophageal ring and an abdominal nerve cord. The supraesophageal ganglion is highly developed; it is also called the head ganglion or the brain. Nerves extend from the latter to the sense organs on the head. Three thoracic ganglia of the abdominal nerve cord are also highly developed. Nerves extend from the latter to the extremities and the wings. The body of a beetle contains numerous epidermal sensitive organs in the form of various hairs and bristles.

The sense organs of insects are capable of perceiving the slightest stimulation. Some butterflies discriminate pure water from a solution by its taste, even if the solution contains only 0.003% sugar; males find females from afar by their smell (the distance may be up to several kilometres).

Auditory organs develop in grasshoppers, crickets, and other insects, who are capable of chirring and "singing". The intricate behaviour of insects is associated with the complicated structure of the nervous system and the high development of the sense organs.

? 1. What is the structure of the digestive system of insects? Name its parts by Figure 58.

△ 2. Do insects have a closed or an open circulatory system?

3. Examine the structure of an insect's heart in Figure 58. Where does the blood flow from the heart?

4. How do insects breathe?

5. What makes nervous system and sense organs of insects more complicated than those of crustaceans?

2.21 Reproduction and Development of Insects

REPRODUCTIVE ORGANS OF A COCKCHAFER. A female cockchafer is slightly bigger than a male, but the plates on its antennae are less developed. The more developed olfactory organs of a male are associated with the fact that they find females by the smell. Swarms of cockchafers fly about in spring in the twilight.

The reproductive organs of the insects are in the abdomen: females have two ovaries, wherein a great number of eggs develop, and in the male there are paired testes, in which numerous spermatozoa are formed.

LARVA. After fertilization and intensive feeding on tree leaves the female burrows into the soil and lays her eggs there. *Larvae* hatch from the eggs at

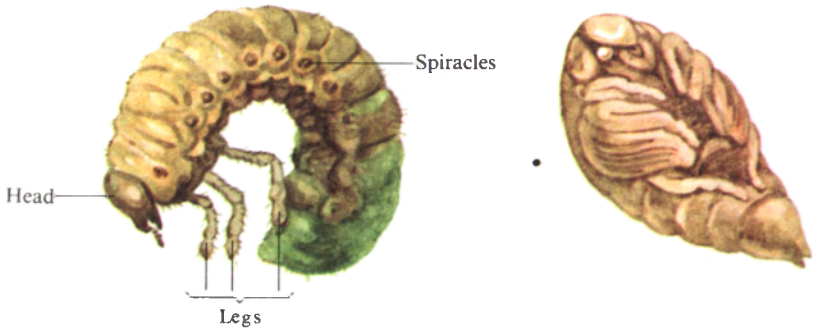


Fig. 59. Larva and pupa of a cockchafer

the end of summer. They are entirely unlike adult beetles in appearance and mode of life. The fat whitish body of a larva is arched and encased in a soft chitinous covering. Denser yellowish-brown chitin covers the big head and the three pairs of legs. The wings are not developed in a larva. Spiracles are seen on the sides of the body. The intestine is visible through the posterior portion of the abdomen. It is filled with earth because young larvae feed on humus. The larvae burrow deep into the soil in autumn and spend the winter there. They migrate to the surface the following spring and during the summer they feed on the roots of herbaceous plants and seedlings of pine-trees. The larvae spend the following winter again burrowed deep into the soil. The following summer (third year of development) the mature larvae feed on the roots of bushes and trees. As a result, young trees can dry up.

PUPA. Having wintered for the third time and grown intensively, the larva burrows into the soil in late spring and, shedding the larval covering, turns into a pupa. The pupa of a cockchafer resembles an adult insect in its appearance. It is possible to distinguish a head with mouthparts and antennae, compound eyes. Legs are folded on the pupa's thorax. There are small wings. The chitinous cuticle of a pupa is colorless and rather dense. The pupa can move its abdomen slightly, but it is unable to move around and feed. This is the dormant stage in the development of the cockchafer. Complex changes, causing development of all the organs of an adult insect, occur under the chitinous cuticle of a pupa on account of the nutrients accumulated by the larva. The pupa's cuticle splits at the beginning of autumn and an adult beetle emerges in a soft colorless covering, which hardens soon and gains the characteristic coloration.

The beetles spend the winter in the soil and come up to the surface only the next spring.

DAMAGE CAUSED BY COCKCHAFERS. During periods of mass flights (once in four-five years), cockchafers may cause great damage to trees by feeding on their leaves, but the main harm is caused by their larvae. Beginning with the second year of life, the larvae of cockchafers feed on the roots of various trees, mainly pine-trees, and damage seedlings and young plants. A cockchafer has natural enemies, namely, starlings, rooks, bats, moles. It is

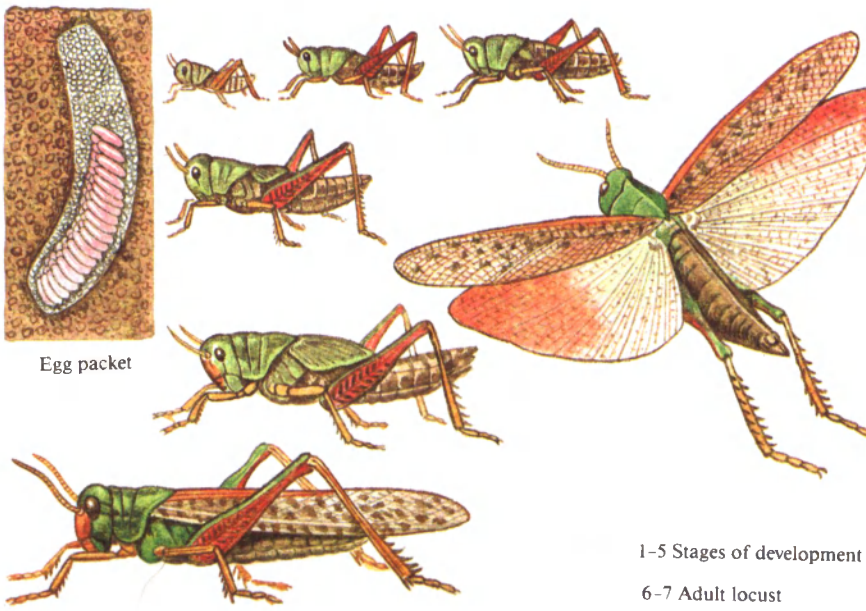


Fig. 60. Development of a locust

necessary to preserve these birds and animals. It is very useful to hang up starling-houses and wild hives in forest nurseries.

DEVELOPMENT WITH COMPLETE METAMORPHOSIS. Using the cockchafer as an example we have learned a complex method of development. A larva, which bears no resemblance to an adult insect, emerges from an egg. The larva feeds intensively, grows, and transforms into an immobile pupa. Complicated processes occur in the pupa, associated with the degeneration of the larval tissues and development of its organs into organs of an adult insect, which comes out of the pupa.

This kind of development, which includes four stages – *egg-larva-pupa-adult insect* – is called *development with complete metamorphosis.* Beetles, butterflies, fleas, mosquitoes, flies, bees, wasps, ants, and some other insects develop according to this type of metamorphosis.

DEVELOPMENT WITH INCOMPLETE METAMORPHOSIS. The larvae emerging from the eggs of cockroaches, locusts, bedbugs resemble the adult insect in its external structure, mode of life, and nutrition. The little larva feeds and grows, molts periodically and resembles increasingly an adult insect after each molt. A pupa is not formed in this case. This development, which includes three stages – *egg-larva-adult insect* – is called *development with incomplete metamorphosis.*

Adult insects neither grow, nor molt.

The class of insects divides into orders. Let's study the representatives of the main orders of insects.

? 1. How do the external structure, mode of life, nutrition of an adult cockchafer and its larva differ?

△ 2. What is the difference between development with complete metamorphosis and development with incomplete metamorphosis?

3. Tell about the life of insects that you have observed in summer in an adult or larval stage.

2.22 Order: Coleoptera, or Beetles

The Colorado potato beetle is the most dangerous pest of potatoes, whose leaves are devoured by adult insects and their larvae. Everyone should recognize the Colorado potato beetle and its larvae to take measures for their extermination. After the potatoes have been gathered, it is necessary to perform deep tillage so that birds could reach the wintering pupas and beetles. Tilled earth freezes to a greater depth in winter and the insects perish.

LADYBIRD BEETLES. WARNING COLORATION. These small beetles with peculiar bright coloration of the elytra are well-known to everyone. Ladybirds and their larvae feed on aphids, who are tiny insects that suck the juice of plants. Aphids reproduce very rapidly and cause great harm to agriculture. Man uses ladybirds with success in the fight against some species of aphids and other insects, who parasitize plants. Ladybirds are bred in special laboratories and then set free in orchards.

If one touches a ladybird, the latter secretes a caustic liquid, that protects the beetle against birds and other enemies. Birds recognize ladybirds by their coloration and leave them alone. Therefore, the bright, well-seen coloration of the ladybirds is called *warning coloration*. The latter is typical of burying beetles, who also secrete a caustic liquid with a disagreeable smell.

BURYING BEETLE AND DUMBLE BUG. One can always find a black beetle with two wide transversal reddish-yellow bands on the elytra in summer near dead bodies of small birds, mice, moles, and other small animals, lying on the ground. It is a burying beetle.

Having a fine sense of smell, the burying beetles congregate from afar around the dead body and burrow into the soil beneath it. They remove the earth from beneath the body, thereby lowering it into the soil. The beetles lay eggs in the soil. The hatching larvae feed on the decomposing body. Burying beetles are considered to be beneficial insects, because otherwise the bodies of dead animals would decompose on the ground surface, thereby infecting the environment.

Dumble bugs are also beneficial, because they dig dung into the soil for the nutrition of their larvae.

Burying and dumble beetles care for their young: the larvae hatching out of the eggs are provided with food that is buried into the soil by the parents.

RARE SPECIES OF BEETLES. Beetles represent the largest order in the

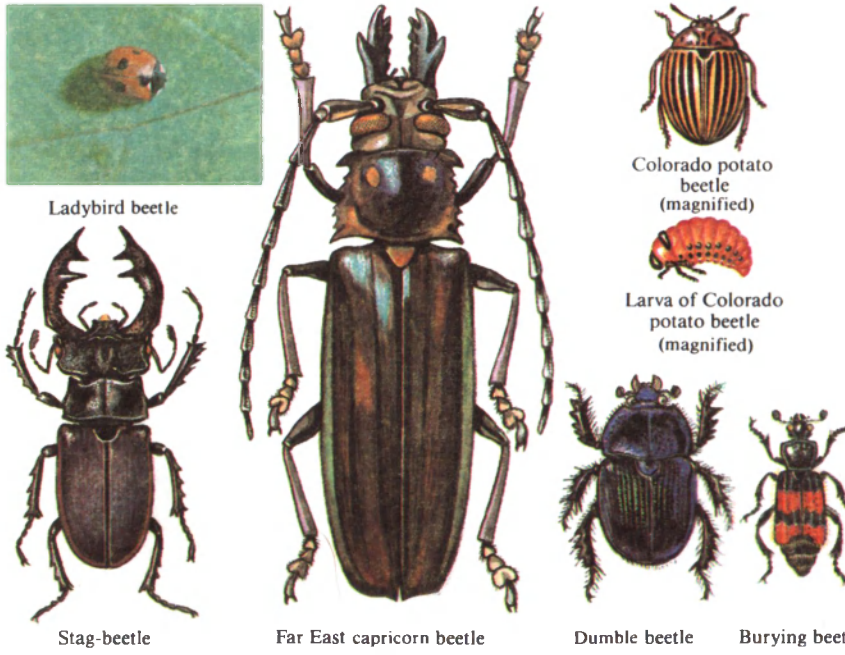


Fig. 61. Beetles

species of insects. Beside the undoubtedly harmful and beneficial beetles, there are many species, who are of no importance for human economy. Some of these beetles are beautifully shaped and coloured. They decorate nature in the same way as beautiful butterflies, birds, and flowers. Therefore, they should be preserved. The beautiful large and harmless stag-beetle (!) is becoming rare in our country and it demands preservation. It is necessary to preserve the Far East capricorn beetle (!), which is dying out, the largest beetle in our country, whose length reaches 10 cm.

2.23 Order: Lepidoptera, or Butterflies

GREAT WHITE OR CABBAGE BUTTERFLY. The cabbage butterfly is widespread in the USSR, as well as other species of white butterflies. White butterflies (Pieris) are called so because of the flour-white coloration of the upper side of the wings. The forewings of a cabbage butterfly have dark corners on the upper side. There are also two dark spots on the forewings of a female, while those of a male are spotless. The coloration of the butterfly's wings depends on the colour of the tiny covering scales. Hence, the name of butterflies: Lepidoptera ("lepid" in Greek means "scale" and "pteron" means "wing").

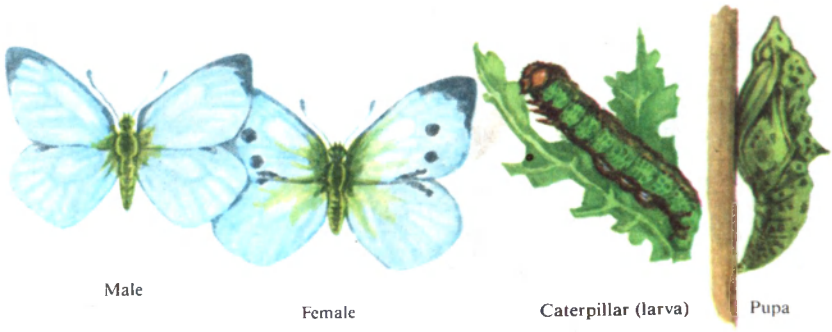


Fig. 62. Cabbage butterfly

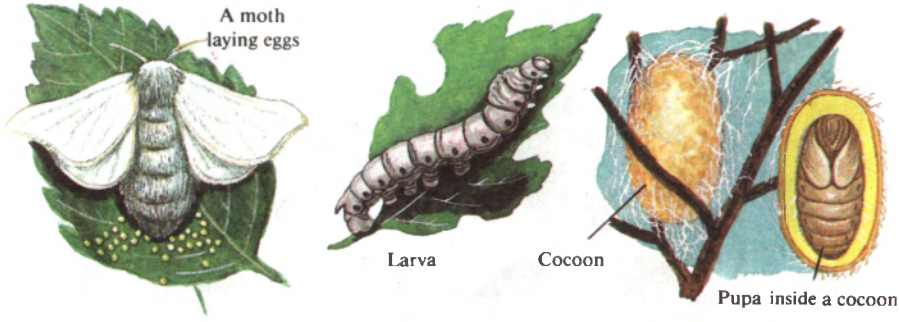


Fig. 63. Silkworm moth

Cabbage butterflies fly about gardens and fields during the spring and summer. When the butterfly settles on cabbage or some other plant, it folds its wings behind its back and becomes invisible: the underside of the butterfly's wings are greenish-yellowish, resembling a leaf. The sense organs of the butterfly are well-developed and the compound eyes enable them to distinguish the colour and shape of objects.

Butterflies feed on nectar. When a butterfly finds and settles on a flower, it tastes the nectar. Its organs of taste are located on the tips of its legs. The mouthparts of butterflies are shaped like a spirally coiled sucking tongue. When sucking, the butterfly straightens the tongue and plunges it into the nectar.

The cabbage butterfly lays eggs on the leaves of cabbage and other cultivated crops and weeds of the Cruciferae family. The eggs of the butterflies develop into *larvae* (*caterpillars*). The larvae have a worm-like body shape, a rounded head with simple eyes and biting mouthparts. Each of the three thoracic segments bears a pair of segmented legs with claws. The five pairs of abdominal appendages with hooked tips are *prolegs*, which are unlike the segmented legs of adult insects.

The larva of a cabbage butterfly is greenish, with black spots and yellowish bands on its sides and back. Its body is covered with sparse short

Fig. 64. Butterflies: *1* – Swallowtail; *2* – Orange Tip; *3* – Mourning cloak; *4* – Moorland clouded yellow; *5* – Common blue, female; *6* – Common blue, male; *7* – Maacks swallowtail; *8* – Red admiral; *9* – Peacock butterfly; *10* – Silver-washed Frityllary; *11* – Small tortous shell; *12* – Ringlet; *13* – Vine sphinx; *14* – Red peacock butterfly; *15* – Brimstone, male; *16* – Brimstone, female; *17* – Garden-tiger moth; *18* – Popular red underwing

hairs. It feeds on the leaves of plants, molts several times and grows rapidly.

A mature larva climbs up a tree, a fence, or a wall, where it sheds its skin and turns into a pupa. The butterfly, emerging from the pupa, has small crumpled soft wings. It sits quietly on one spot for several hours until the wings unfold and strengthen.

SILKWORM MOTH AND SERICULTURE. These white moths with a downy body have been bred by humans for more than 4000 years for the sole purpose of producing silk. They have become domestic animals, lost the ability to fly and do not occur in nature.

The larvae, hatching from the eggs in special rooms, feed on mulberry leaves. The grown up larva spins a cocoon of web that is secreted through the mouth from the silk glands and hardens into a thin filament. The sole purpose of breeding silkworm moths is to produce these silk filaments.

The larva sheds its skin inside the cocoon and turns into a pupa. The pupa is suffocated in the cocoon, then the filament is unwound from the cocoon and is subjected to further processing.

The silk filaments feature many valuable properties: they are beautiful, strong, keep heat very well. They are used in medicine (to suture wounds during operations). Both light and strong silk fabrics are used in aviation (for making parachutes, balloons, stratosphere balloons).

? △

1. What is the difference between the mouthparts of an adult butterfly and a larva?
2. Is incomplete or complete metamorphosis observed in the development of butterflies?
3. What specific features in the structure of the mouthparts and wings of a butterfly make it unlike insects of other orders?
4. Look at Figure 64. Read the names of species of the butterflies in the figure. (Remember, that the majority of diurnal species of butterflies are harmless.)
5. Referring to the Subject Index, compare the meaning of cocoon (see term "cocoon") in the life cycle of worms, spiders, and butterflies.

2.24 Order: Diptera

Houseflies are known to everyone. Its body is of a gray-brownish colour, the forewings are transparent and well-developed. The hindwings of a housefly, as in all other dipterous insects, are modified into balancers which are organs of equilibrium. The mobile head bears short antennae and large compound eyes. Flies run about adroitly on sugar, bread, pies, and other foods and dishes; the organs of taste are at the tips of their legs. The lower lip of a fly is modified into a beak. A fly feeds only on fluid food and regurgitates from the intestine some of its digestive juice to dissolve the food, and then sucks it up by the beak.

The larva of a fly is worm-like. It is white, headless and legless. It grows rapidly and transforms into a reddish-brown pupa that is shaped like

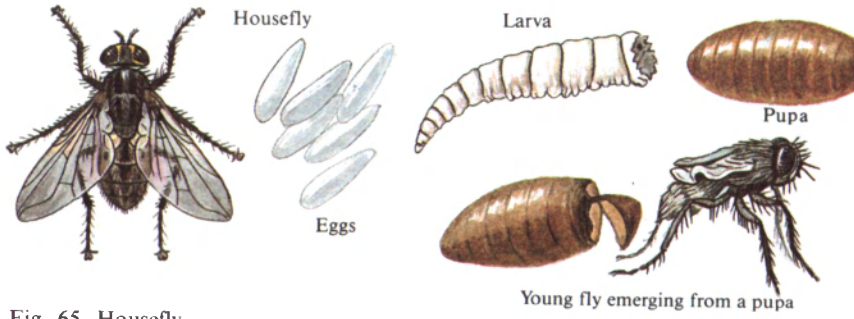


Fig. 65. Housefly

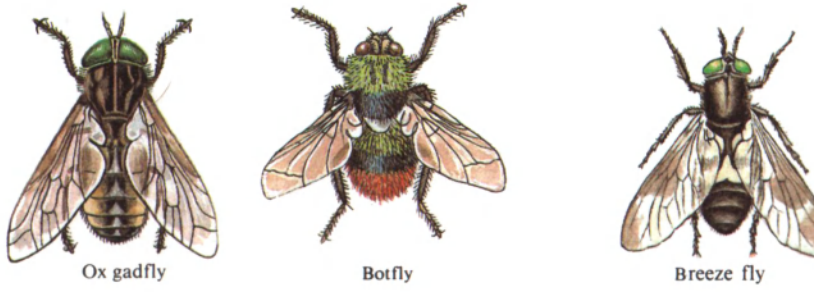


Fig. 66. Two wings

a barrel. A fly emerges from the pupa. About five to ten generations of flies develop in the course of one summer.

The larvae of flies develop in dung heaps, toilets, drain pits. The dirtier the human environment (inside and around the house), the more favourable the conditions for the reproduction of flies. Adult flies may visit human dwellings after returning from toilets and drain pits, settle on food and transmit pathogenes of various diseases (typhoid fever, dysentery, etc.).

It is necessary to fight with flies: eliminate them by various methods, keep the home and barnyard clean inside and outside.

GADFLIES. Gadflies, resembling very large flies, congregate around horses and cow herds on sunny summer days. Female gadflies pierce the skin of domestic cattle and humans with their mouthparts and suck the blood with their beaks. The larvae of gadflies develop in moist soil or in water.

BOTFLIES. Botflies are often confused with gadflies. Botflies also attack domestic animals, but not for feeding. Its purpose is to lay eggs on the animal's coat. When a larva of a botfly hatches from an egg, it bores into the skin of horned cattle. It feeds and grows intensively during the winter, forming an ulcer in the skin of the host. The parasitizing larvae of botflies reduce the milk yield considerably. The skin of the infected animals have damaged spots that devaluate the hides. Various drugs, which kill

the larvae, are injected into diseased animals in the fight against skin botflies.

Adult botflies don't feed, because their mouthparts are underdeveloped.

? △
1. How do Diptera differ from other insects?
2. What type of development do Diptera follow?
3. Why is it necessary to eliminate houseflies?
4. What harm do botflies and gadflies bring to domestic animals?

2.25 Order: Hymenoptera

Honeybee

BEES ARE SOCIAL INSECTS. They live in big colonies. Each honeybee colony includes one big female, who is the *queen*, several hundred males, *drones*, and many thousand *workers*. The workers are underdeveloped females, who are incapable of reproduction. A bee colony settles usually in the hollow of a tree, or in special wooden houses, called *hives*, if bees are raised artificially. The bees make wax combs, comprised of numerous hexagonal cells.

STRUCTURE OF A WORKER. The bee has a big head covered with hairs,

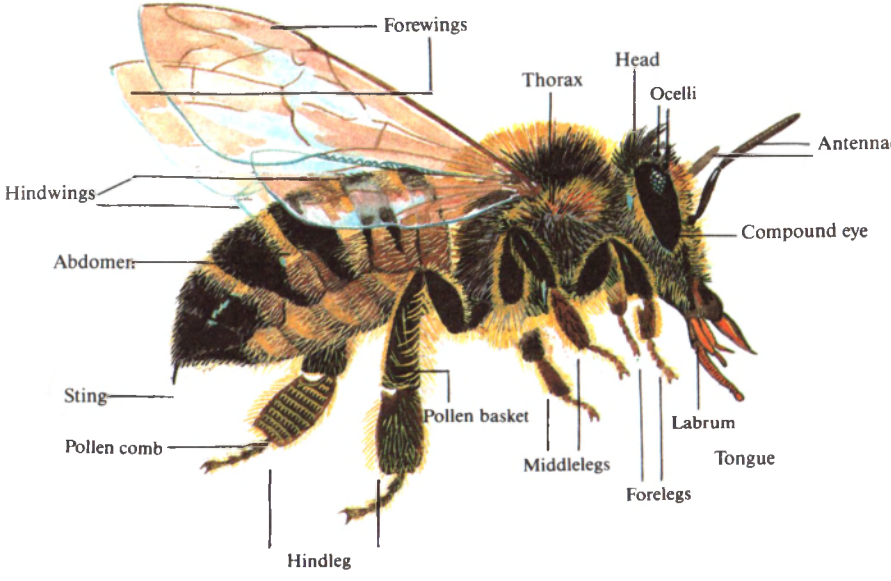


Fig. 67. External structure of a honeybee. Diagram

Fig. 68. Bees

and there are two compound eyes on the sides with three simple eyes between them. Long, bent antennae extend forward.

The sense organs are very important in the life of bees. Tactile organs, located mainly on the antennae, are most important in the dark hive. The senses of smell and vision are very important when the bee looks for flowers. Bees distinguish yellow and blue colours, and even ultra-violet rays that are invisible to the human eye, but they don't see anything red.

The biting upper jaws of the bee are well-developed. She uses them to knead and treat wax when building cells, and to remove the pollen from the stamens when she visits flowers. The bee uses the maxillae and the long lower lip to lap and suck the nectar, therefore the mouthparts of a bee are called *biting-lapping* ones.

The nectar, sucked from a flower by a bee, is drawn into a bulky crop and mixes with the secretion of the crop glands. Then bees put the nectar into comb cells, wherein it transforms into honey.

The thorax of a bee is covered densely with hairs, and two pairs of semitransparent membranous wings are on her back. The legs of the worker are adapted to collect pollen and to build cells in the combs. The worker has a sting at the posterior end of the abdomen. When the worker drives the sting into the body of an animal or a human, poison enters the wound, causing acute pain. The poison is lethal for small animals.

LIFE IN A BEE COLONY. The workers emerge from the hive after winter hibernation at the beginning of the warm season in spring. When the first flowers start to blossom, they begin to collect pollen and nectar. The queen lays eggs into the cells of the comb. The bees feed the larvae, which hatch from the eggs, with a mixture of honey and flower pollen. The larvae of queens and drones develop in larger cells.

SWARMING. Swarming starts shortly before the emergence of a young queen, when the old one and a part of the workers leave the hive. The emerging swarm settles on a tree branch, forming a ball around the queen. It is removed into a sack and carried to a new hive.

In the second half of the summer the bees store up reserves of honey for the winter. When the cold season begins, the bees wax up all the slots in the hive and prepare for wintering. In winter they keep in a tight cluster in the cells and feed on the stored honey.

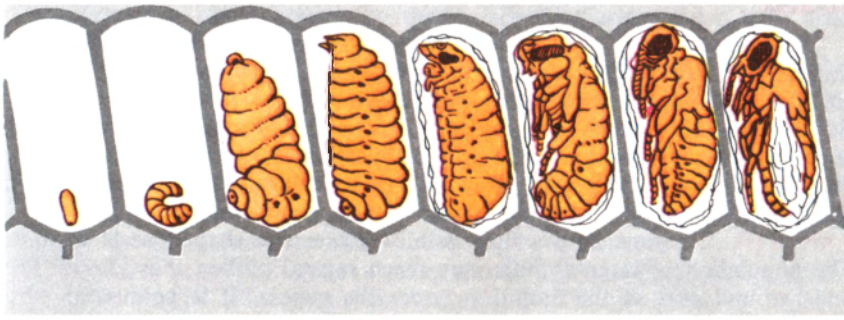


Fig. 69. Development of a bee in a comb. Diagram

BEE COMMUNICATION. A bee, having located blossoming flowers with a copious flow of nectar, returns to the hive. She begins to whirl on the combs, wagging her abdomen from side to side. Observations have shown that this "dance" is a form of "sign language" of the bees. The steps of the "dance" tell the bees in what direction and how far they should fly for the honey flow. On arriving at the place of assembly, the bees settle on the flowers, whose scent the first bee brought to the hive.

INSTINCT. When studying the life of bees, one would think that their behaviour is reasonable, because all the actions are strikingly expedient. However, observations and experiments indicate that it is not quite so. Bees learn neither the art of construction nor any "language": these abilities are innate. Bees and other animals (for example, a spider spinning a web, or a burying beetle who buries a dead animal) do not imagine the results of their activities. The complex activities of bees consist of many successive reflexes. This succession of reflexes, manifested in the complex behaviour of animals, is called instinct. All the activities of bees are instinctive, including the building of combs, collection of nectar and pollen, feeding of larvae, swarming, etc. Unlike animals, a human always imagines the results of his/her labour.

Bees are greatly beneficial in many ways. Bees give us nourishing and medicinal honey, as well as wax which is used for various technical purposes. Bee venom has beneficial properties also, and it is used for treating rheumatism and other afflictions. Bees play an important role in pollinating many plants.

?
△

1. How do bees produce honey?
2. How does a bee defend itself against enemies?
3. What is instinct?
4. What valuable products does man get from bees?
5. Give examples of instinctive behaviour by your observations of animals under natural conditions.

2.26 Diversity of Hymenopterans

Bumble-bees (!) are large (up to 30 mm long), hairy, and brightly coloured hymenopterans. Like bees, they live in colonies, but only several dozen individuals may be present in a colony. Bumble-bees build their nests under stones, in the ground, and cover them inside with grass blades and moss. The bumble-bees pollinate plants when they collect nectar and pollen. They play an important role in the pollination of clover. Bumble-bees and their nests should be protected.

ANTS (!). Everyone knows that anthills are cupola-shaped nests of ants. The population of large anthills may reach several million individuals. The underground part of the anthill is under the cupola. It is permeated with numerous passages, wherein the young develop. Ants live in groups of numerous families for many years, consisting of females, males, and workers, just like bees.

An ant has a mobile head with well-developed biting upper jaws. The head bears compound eyes and bent antennae. Their legs are well-developed. Females and males have membranous wings that break off easily. The abdomen is very narrow between the first and second segments, making it very mobile. Some species of ants have a sting at the posterior end of the abdomen to discharge poison.

Unlike bees, a division of labour exists among worker ants, for example, the bigger ones with very large heads, or with powerful jaws, are soldiers. They stand in the anthill at each exit and block it with their heads. When a returning worker approaches the closed entrance, it knocks with its antennae on the head of the soldier, who lets him in after receiving this sign.

Soldiers with powerful jaws can attack the nests of other ant species. Workers with swollen abdomens devour the nectar of flowers and honey from honeybee hives. They regurgitate the honey and feed other workers upon returning to the anthill. Some worker ants breed aphids and take care of them. The ants feed on the sweet secretions of the aphids. Worker ants of some tropical species cultivate mushrooms and moulds under the ground surface and use them to feed the larvae. As in the case of bees, all these activities of ants are instinctive.

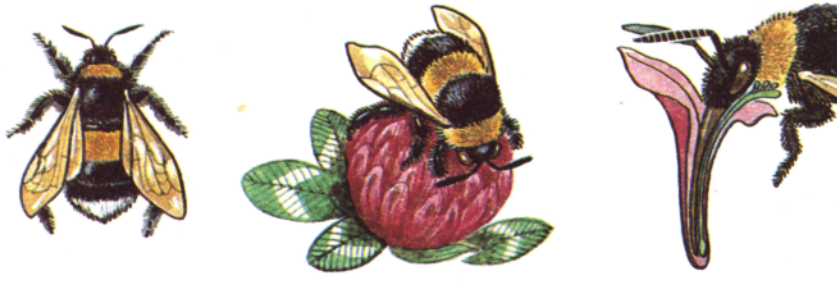


Fig. 70. Bumble-bee

Ants spend winter in the underground part of the anthill, where the temperature is not as low as on the surface. Gathering into a tight cluster, they stay there until spring.

Ants feed mainly on insects. It has been calculated that an ant family brings about 1 kg of insects every day to the anthill, including caterpillars, butterflies, beetle larvae. The majority of these insects are pests of the forest and cultivated crops. Ants are useful in eliminating these pests.

Ants are also beneficial because, like those of earthworms, their passages loosen the soil, contributing to its aeration and humidification, and help to enrich it with humus. Anthills should not be destroyed!

ICHNEUMONS. The larvae of many species of hymenopterans are parasites of other insects. Ichneumons are the most well-known ones.

The female of a white's ichneumon (Apantheles) finds a caterpillar of a cabbage butterfly and straddles it. Then the ichneumon pierces the skin of the larva with a long thin appendage, an *ovipositor*, which is located at the posterior end of the abdomen, and deposits eggs within the host. The ichneumon larvae that emerge from the eggs feed on the tissues of the caterpillar. On reaching their maximal size, the ichneumon larvae bore through the skin of the caterpillar and emerge, while the latter perishes.

BIOLOGICAL METHOD OF PEST CONTROL. Ichneumons and other parasitic insects are very useful, because they eliminate pests of agricultural

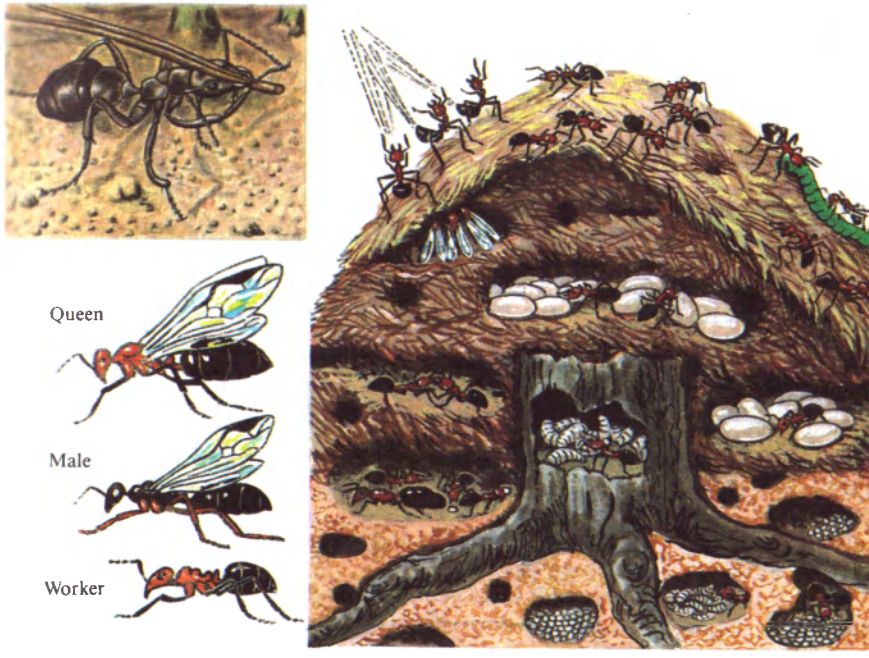


Fig. 71. Ants and an anthill

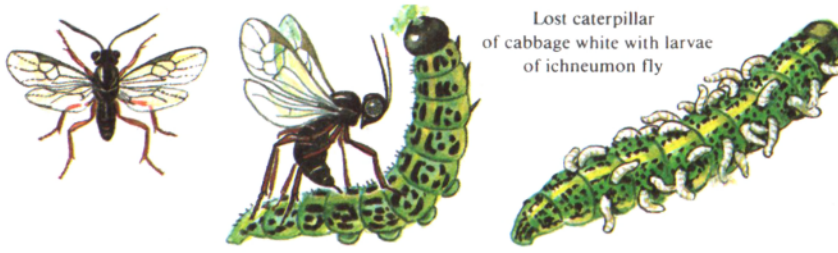


Fig. 72. White's ichneumon fly and caterpillar of cabbage butterfly (magnified)

and valuable wild plants. The same benefit is derived from some predatory insects (recall the ladybird). Therefore, parasitic and predatory insects of certain species are bred artificially at laboratories and are let out in large numbers in fields, orchards, gardens, and forests.

The extermination of harmful insects by means of natural enemies is called a *biological method* of pest control.

? 1. What hymenopterans do you know?
2. In what way are ants useful?
△ 3. Tell about the life of ants from the materials of your summer observations.

2.27 Order: Orthoptera

A migratory locust is a large insect (about 5–6 cm long) with short antennae, long, narrow, leathery, straight forewings (hence the name of the order: Orthoptera), wide, fan-shaped folding hindwings, and long jumping hindlegs.

Migratory locusts live and reproduce in the reed banks of water bodies. They occur in the USSR in the lower reaches of the Kuban, Terek, Urals, Syr Darya, Amu Darya Rivers.

A female locust works her short ovipositor into the ground and lays eggs there during the second half of summer. The eggs of the locust are glued together into an elongated packet. Larvae, resembling adult insects but lacking wings, emerge from the eggs in spring. The larvae gather together. They feed, grow, molt, and turn gradually into adult winged locusts.

After reproduction a locust can migrate long distances from its permanent habitat, settling on cultivated crops.

Locusts are very voracious. It has been calculated that the offspring of one female can devour during their stage of development more than 300 kg of fresh plants. Locusts feed on plants of any species.

Individual human beings cannot fight locusts, and the struggle is

Fig. 73. Walking stick

Fig. 74. Grasshopper

conducted by special locust control stations. The fields and orchards of our country are reliably protected today against this pest.

CRYPTIC COLORATION. The green grasshopper greatly resembles a locust, but differs from it by its longer thin antennae. The long sabre-shaped ovipositor is at the posterior end of the female grasshopper's abdomen. She works the ovipositor into the ground and lays eggs. The green colour of the grasshopper's body makes the latter inconspicuous in summer among plants, though its chirring is audible in meadows from all sides. This coloration protects the grasshopper against enemies (for example, insectivorous birds). A mantis (a large predatory green insect) is inconspicuous to its prey (flies, butterflies). The similarity between the colour of an animal and that of its environment is called *cryptic coloration.*

The shape of the body is also of protective importance. For example, a walking stick resembles the branch on which it sits.

? Which insects that we have studied have cryptic coloration?

2.28 The Role of Insects in Nature and Their Practical Importance for Man

ABUNDANCE OF INSECTS. Insects represent the most numerous class of animals, containing more than a million species. Calculations made by scientists indicate that about 10^{17} (100 000 000 000 000 000) individual insects live simultaneously. Insects play an important role in nature and in the life of mankind because of their abundance.

IMPORTANCE OF INSECTS IN NATURE. Insects inhabit land and fresh-water bodies high and low, wherever life is possible. They live high up in the mountains, in deserts and in arctic regions. The only place where insects

never occur is in seas. The importance of insects in nature is quite varied because of their prevalence.

The life of many insects is closely associated with the life of plants. A tremendous army of these arthropods feeds on leaves, roots, stalks, and other organs and parts of plants, fruits, and seeds. In the case of mass reproduction, phytophagous insects damage or exterminate plants on vast territories. However the beneficial affects of insects in the life of plants are very great. As you know, ants contribute to soil formation. Bumble-bees, honeybees, flies, and some species of butterflies and beetles contribute greatly to the cross-pollination of flowering plants.

Insects are very important in the organic cycle of matter in nature. Feeding on vegetable food, they themselves become the prey of other animals (for example, insectivorous birds). Such insects as burying beetles and dung bugs are of great sanitary significance.

Life on the Earth would be impossible without the plurality and high activity of insects.

IMPORTANCE OF INSECTS IN THE LIFE OF MAN. Man encounters various insects in his everyday life and practical activities. Some of them are beneficial, while others cause a detrimental effect. The honeybees and the silkworm moths are highly beneficial. Insects who are pollinators of cultivated and valuable wild plants are obviously beneficial, as well as soil-forming (pedogenic) and sanitizing insects, and parasitic and predatory ones who exterminate pests of useful plants. These insects are gaining increasing importance owing to the development of biological methods of pest control.

Harmful insects are those that damage crops, forests, orchard trees, and other valuable plants, eat and damage foods, industrial raw materials (wood, leather, etc.), woollen clothes (the larvae of clothes moths feed on wool). There are insects that cause damage to furniture and destroy wooden structures.

Blood-sucking insects (mosquitoes, gadflies, etc.) reduce the yield of dairy cattle, annoy people at work and at leisure. Malaria mosquitoes transmit malaria parasites from diseased to healthy people, flies contribute to spreading intestinal diseases, fleas transmit plague.

Man should consider the importance of insects, preserve and breed useful ones, and fight against harmful ones.

? 1. What is the importance of insects in the life of plants and in the organic cycle of matter in nature?

△ 2. What insects does man use to produce foods and industrial raw materials?

3. Which insects cause damage to the human economy in general, and which ones are detrimental to man directly?

4. What orders of insects have you learned?

2.29 Similarities and Differences Between Classes of Arthropods. Origin of Arthropods

The resemblance between various classes of arthropods is very great. The body and legs of all the arthropods are divided into sections. The coverings of these animals are hard and consist mainly of chitin. The internal structure of arthropods is also similar: the circulatory system is open, the heart is on the dorsal side of the body.

The similarity of arthropods and annelids is quite great. The body of annelids and arthropods is comprised of segments, the extremities of arthropods correspond to the paddle-shaped appendages on the body of polychaete annelids. A circulatory system is developed in representatives of both phyla.

The central nervous system of arthropods and annelids is in the form of an abdominal nerve cord with a circumoesophageal (or circumpharyngeal) nerve ring and ganglia.

The structural resemblances between the classes of arthropods and between the phyla of arthropods and annelids are not accidental. They testify to the relationship between these groups of animals and proves that arthropods evolved from annelids. Scientists believe that crustaceans, arachnids, and insects evolved from ancient marine polychaete worms independently of one another and in different time periods. The difference in the structure of the respiratory organs in various classes of arthropods, as well as the difference in the segmentation of the body of representatives of various classes support this assumption. Crustaceans have preserved the greatest resemblance to annelids. Like marine annelids, they inhabit aquatic habitats, and breathe through gills.

Insects and arachnids turned to terrestrial habitats, consequently developing air respiratory organs. However, the lungs of spiders and the tracheae of insects differ in structure, meaning that the ancestors of arachnids and insects were not entirely similar.

Insects adapted best to the terrestrial mode of life. Representatives of this class learned to fly owing to the development of wings. Some insects or their larvae started to live in water, but they did not settle in the sea, where their polychaetous ancestors lived, but in fresh-water bodies.

The larva of more ancient insects gradually transformed into adult animals (incomplete metamorphosis). Insects that undergo more complicated (complete) metamorphosis appeared at a later time. Hymenopterans attained maximal development in terms of complexity of structure and behaviour.

Phylum: Chordata

Class: Cephalochordata

2.30 Lancelet – Lower Chordate

MODE OF LIFE AND EXTERNAL STRUCTURE. Lancelets, tiny semi-transparent animals (4–8 cm long), occur in many tropical and warm-temperate seas, including the Black Sea, at shallow depths in areas with a clean sandy bottom. The pink body of the lancelet is compressed on the sides and pointed at both ends. The posterior end of the body is framed by a dorsal fin which resembles a double-edged surgical instrument, a lancet (hence the name: Lancelet). The lancelet spends the majority of time buried in the sand, with only the anterior end exposed, where the mouth is located, framed by 10–20 pairs of tentacles. When it is disturbed, the lancelet swims away a little and again burrows into the bottom.

NOTOCHORD. CHORDATES. The *notochord* extends along the dorsal side of the body. It is a tight, resilient cord composed of peculiar cells that are snug against one another. The notochord functions as an internal skeleton. It is the supporting structure for the internal organs and provides the lancelet's body with a certain flexibility, which is very important for burrowing into the sand. The lancelet has a notochord throughout its entire life.

We shall learn later of other animals who possess a notochord in the adult or only in embryonal stages. They are all united into the phylum Chordata by this common feature.

Beside the lancelet, fishes, amphibians (frogs, newts, etc.), reptiles (lizards, snakes, turtles, crocodiles), birds and animals are also referred to as chordates.

The muscles of the lancelet are located on both sides of the notochord in the form of two bands. The lancelet performs quite monotonous movements. It swims and burrows into the soil by twisting its body back and forth.

The digestive system of the lancelet is very simple. The oral cavity leads into a long wide pharynx, which turns into an intestine that opens externally on the ventral side of the body just anterior to the tail. The oral cavity of the lancelet is covered on the inside with ciliated cells. The latter create a continuous water current, carrying unicellular algae and protozoa, serving as food for the lancelet, through the mouth into the pharynx and further into the intestine.

Respiration occurs simultaneously with feeding. The walls of the pharynx are perforated by about a hundred pairs of gill slits that are surrounded by the capillaries of the circulatory system in the tissues of the pharynx. The water driven in by the ciliated cells, passes through the gill slits and is then discharged from the organism. The gill slits are not visible on the outside because they are covered by folds of skin that protect them against grains of sand.

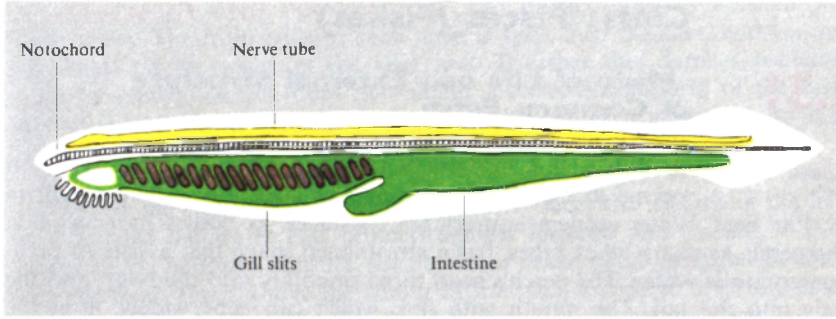


Fig. 75. Structure of lancelet. Diagram

The circulatory system is a closed one and consists of two major blood vessels, dorsal and ventral, as well as numerous branches and capillaries. Blood, saturated with gaseous carbon dioxide, flows forward through the ventral vessel toward the gill capillaries, where it gives off carbon dioxide and is oxygenated. The blood flows back from the gills through the dorsal vessel to the different organs of the body and then again recirculates to the gills. The lancelet possesses no heart and the blood circulates in the system by means of contractions of the walls in several blood vessels.

The excretory organs of the lancelet are of the same structure as that in annelid worms.

NERVOUS SYSTEM AND SENSE ORGANS. The spinal cord, shaped like a long hollow tube, is the central part of the nervous system. It is on the dorsal side of the lancelet's body immediately above the notochord. Numerous nerves branch off from both sides of the spinal cord. The spinal cord in other chordates is similar in structure.

The lancelet discriminates light from darkness though it lacks true eyes. Light is perceived by a cluster of light-sensitive cells located above the nerve tube. Tactile cells are found on the lancelet's body surface.

Academician Alexander Onufrievich Kovalevsky, examining in detail the development and structure of the lancelet, determined that the lancelet is a true chordate by many features (presence of a notochord, structure and arrangement of the nervous system, etc.). At the same time, the structure of the organs of digestion, blood circulation, excretion and nutrition indicate the relationship between the lancelet and such animals as annelid worms and mollusks. The study of its structure assists scientists in determining the origin of all chordates, including humans.

? 1. What features in the structure of a lancelet help us to judge of the origin of chordates?

△ 2. Using the Diagram of the Animal World (inside front cover) and Table of Contents, list the classes that belong to the class Chordata.

Class: Pisces (Fishes)

2.31 Mode of Life and External Structure of Common Perch

A PERCH IS A COMMON DWELLER OF FRESH WATERS. It occurs in the USSR in rivers and lakes everywhere except in the Far East. Water renders appreciable resistance to bodies moving in it. The perch, as many other fishes, has a streamlined shape that assists its rapid locomotion in water. The perch's head turns smoothly into the body, and the body into the tail. The mouth with lips, which can gape widely, is at the anterior pointed end of the head.

Two pairs of small pits, which are *nares* or *nostrils* leading to the olfactory organ, are located dorsally on the head. Two big eyes are located on the sides of the head.

FINS. The perch moves forward by bending its body, which is flattened on the sides, and its tail from side to side. The *fins* are very important for swimming. Each fin consists of a thin dermal web, which is supported by bony fin rays. When the rays spread wide apart, the skin between them stretches and the fin surface area expands. There are two *dorsal* fins on the perch's back: a big anterior one and a smaller posterior one. The number of dorsal fins is different in various fish species. A big double-blade *caudal* fin is at the end of the tail, and an *anal* fin is on the underside of the tail. All of the fins discussed so far are unpaired. Fishes also have paired fins, and there are always two pairs. The paired *pectoral* fins (anterior pair of extremities) are on the sides of the perch behind the head, and the paired *pelvic* fins (posterior pair of extremities) are on the underside of the body. The caudal fin plays the major role in forward locomotion. The paired fins are important for turning, stopping, for slow forward movement, and for the preservation of equilibrium.

The dorsal and anal fins provide the fish's body with stability during forward movement and sharp turns.

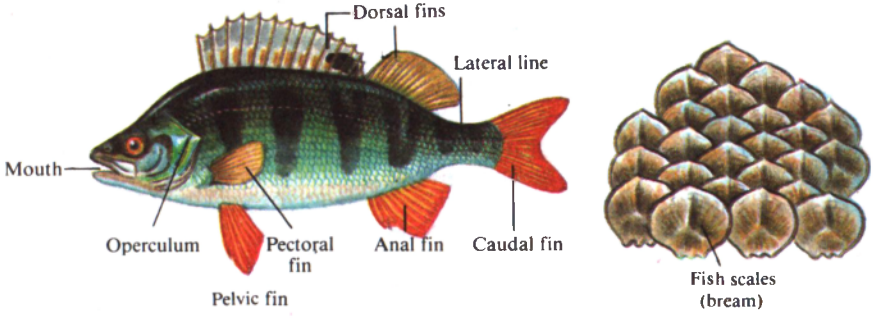


Fig. 76. External structure of a perch. Diagram

INTEGUMENT AND COLORATION. The perch's body is covered with bony scales. The front edge of each scale is sunk into the skin, and the rear edge rests on the scales of the next row. Together they form a protective scaly integument, which does not hinder forward locomotion of the body. The scales increase in size as the fish grows, therefore it is possible to learn the age of the fish by the size of their scales.

The scales are covered on the outside with a layer of mucus that is secreted by the cutaneous glands. The mucus reduces the friction of the fish's body against the water and protects against bacteria and moulds.

Like in the majority of fishes, the abdomen of the perch is lighter in colour than the back. From above the colour of the back blends to a certain extent into the dark background of the bottom. The light abdomen is less noticeable from beneath on the light background of the water surface.

The coloration of the perch depends on the environment. It is dark in forest lakes with a dark bottom, and sometimes even black perches occur in these lakes. Perches with a light and bright coloration dwell in water bodies with a light sandy bottom. Perches often hide in thick vegetation, where the greenish colour of its sides with vertical dark stripes makes the perch inconspicuous. The cryptic coloration helps the perch to hide from enemies and to catch a prey.

A narrow dark *lateral line* runs along the sides of the perch from the head to the tail. This is a special sense organ, whose structure and significance we shall study later.

? 1. What is the role of the various fins in the locomotion of fishes?
2. What is a fish's body covered with? What is the significance of this covering in the life of fish?

△ 3. What is the significance of the perch's coloration? How does it depend on the environmental conditions? Give other examples of cryptic coloration of animals.

■ Observe swimming fishes in an aquarium. Pay attention to the movements of the various fins.

2.32 The Skeleton and Musculature of Fish

The skeleton of a perch is comprised of a large number of bones. Its base is the *spinal column*, that extends along the entire body of the fish from the head to the caudal fin. The spinal column is formed of a large number of *vertebrae* (a perch has from 39 to 42 vertebrae).

Fish and other animals whose skeleton is based on a spinal column are called *vertebrates*, and all other animals are *invertebrates*.

When a perch develops in an egg, a notochord appears at the place of the future spinal column. Vertebrae grow later around the notochord.

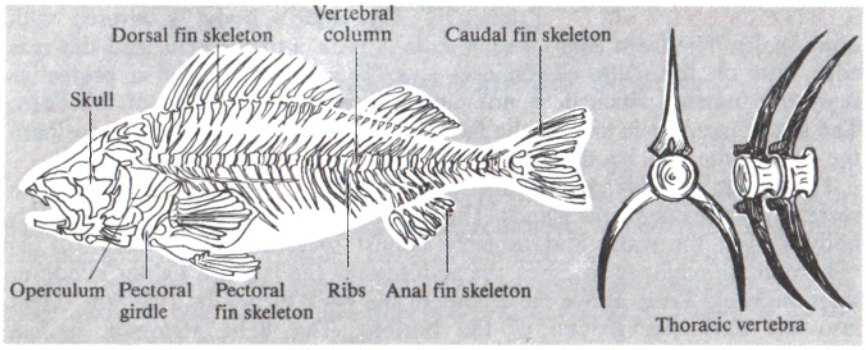


Fig. 77. Skeleton of a perch. Diagram

From the notochord, an adult perch preserves only small cartilaginous traces between the vertebrae. The notochord is preserved in a beluga, sturgeon, and in some other fish species, as well as in a lancelet throughout its whole life.

Each vertebra consists of a *body* and an *upper arch*, terminating in a long upper outgrowth. The upper arches jointly form the vertebral canal, which contains the spinal cord.

Ribs are joined to the sides of the vertebrae in the trunk of the body. There are no ribs in the tail. Each vertebra in the tail consists of a bottom arch, terminating in a long bottom outgrowth.

The *skull*, which is the skeleton of the head, is attached to the anterior end of the spinal column. The fins also have a skeleton. It is joined in the paired pectoral fins to the spinal column by the bones of the *pectoral girdle*. The bones joining the skeleton of the fins to the spinal column are not developed in a perch.

The skeleton is very important: it serves to support the muscles and protect the internal organs.

MUSCULATURE OF FISHES. Muscles which form the musculature are attached to the bones under the skin of fishes. The stronger muscles are located on the dorsal side of the body and in the tail. Contraction and relaxation of the muscles cause the body to bend which helps the fish to move in water. Muscles in the head and fins move the jaws, operculums, and fins.

? 1. What are the main parts of a fish's skeleton? (Use Figure 77 in your answer.)

△ 2. What is the importance of a fish's skeleton as a whole, and of its separate parts?

3. What fish, a perch or a sturgeon, is closer to a lancelet in the structure of its skeleton?

■ Take a small, well-cooked fish, carefully remove its skin with the scales, and examine the structure of the musculature on the back

and in the tail. Separate the muscles, examine the skeleton and find its parts: skull, spine, ribs, skeleton of the fins. Remove a vertebra from the trunk. Find the body of the vertebra and the upper arch. Compare it with a vertebra in the tail.

2.33 Internal Organs of Fish

BODY CAVITY. A large cavity containing the internal organs is located in the trunk of the fish under the spine.

DIGESTIVE SYSTEM. A perch is a predator. It feeds on various aquatic animals, including fishes of other species. A perch grabs its prey and holds it in its jaws with sharp teeth. When the food is swallowed, it passes through the pharynx and esophagus into the stomach. A perch swallows its prey whole, as its stomach can expand greatly. Microscopic glands in the walls of the stomach secrete gastric juices which digest the food. The partially modified food passes then into a thin gut, wherein the digestive juice of the pancreas and the bile from the liver act on it. A store of bile accumulates in the gallbladder. The nutrients are absorbed through the walls into the blood, and the undigested remains are forced into the rectum and excreted.

SWIM BLADDER. A perch, as many other species of fish, contains a peculiar thin-walled gas-filled chamber, a *swim bladder*, situated in the dorsal part of the abdominal cavity. The connection between the bladder and the intestine in an adult perch is lost, while its larvae and some other fishes (for example, roach and carp) have a small tube connecting the intestine and the bladder. When the fish dives to the bottom, the volume of the bladder reduces and the density of the fish increases, which contributes to rapid sinking.

When surfacing, the volume of the bladder increases and the fish becomes relatively lighter. The bladder's volume remains invariable when the fish stays at the same depth, making it possible for the fish to stay immobile, as if it is suspended in the water.

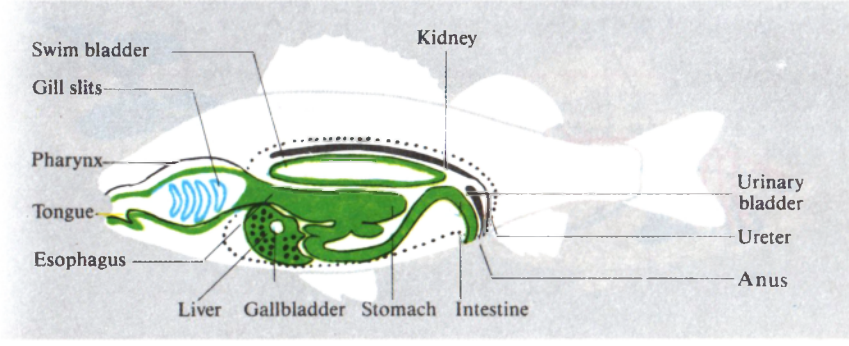


Fig. 78. Digestive and excretory system of a perch. Diagram

RESPIRATORY SYSTEM. Fishes take in oxygen that is dissolved in the water.

A fish swallows water continuously. The water flows from the oral cavity through the *gill slits* that permeate the walls of the pharynx and wash the respiratory organs, the *gills*. A perch has *gill arches* (branchial arches), each one bearing a bright-red *gill filaments* on one side, and whitish *gill rakers* on the other. The gill rakers represent a filtering apparatus: they prevent escape of the prey through the gill slits. The gill filaments are permeated with tiny blood vessels, capillaries. Oxygen dissolved in the water penetrates into the blood through the thin walls of the gill filaments, while carbon dioxide is eliminated from the blood into the water.

If the amount of oxygen is insufficient, they surface and catch air with their mouth. Fishes perish if they stay for a long time in water containing little oxygen. Sometimes there is little oxygen in ice-covered water bodies in winter, and the mass death of fish occurs. It is advisable to make holes in the ice to prevent the mass death of the fish.

Dry gill filaments are unable to pass oxygen and carbon dioxide. Therefore, a fish perishes rapidly when it is removed from the water. The tender gills are covered on the outside with protective *operculums*.

The circulatory system of a fish is a closed one. It comprises a heart and vessels. The vessels extending from the heart are called *arteries*; the vessels carrying blood to the heart are called *veins*. The heart of the fish is a two-chambered one. It is comprised of an atrium (auricle) and a ventricle, muscular walls of both chambers contract alternately. The blood is forced from the auricle into the ventricle, from where it is discharged into a large artery, the *ventral aorta*.

Backflow of the blood is prevented by *valves*. The abdominal aorta extends to the gills. Smaller vessels branch off to the right and to the left from the aorta. The circulating blood is dark in colour. It is saturated with carbon dioxide and is called *venous* blood. In the gills the vessels branch into capillaries, wherein the circulating blood is freed of carbon dioxide and is oxygenated. Scarlet, oxygenated *arterial blood* is carried through the vessels,

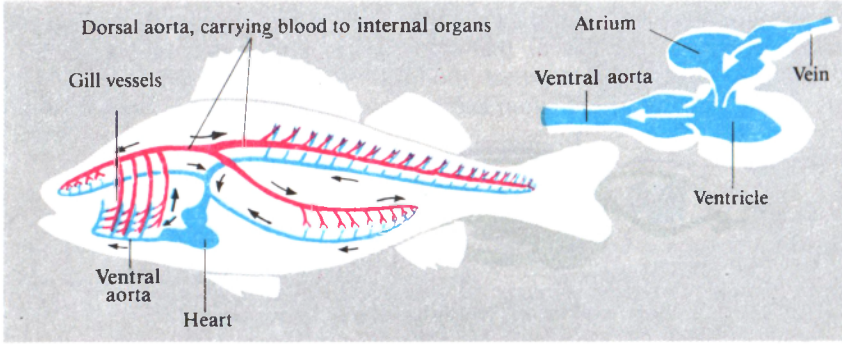


Fig. 79. Circulatory system of a perch. Diagram

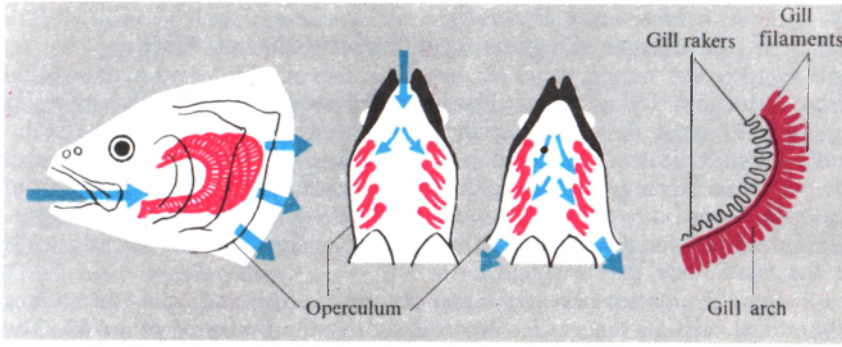


Fig. 80. Structure and work of gills. Diagram

extending from the gills. It is collected in the *dorsal aorta* which extends along the body under the spine. The dorsal aorta extends into the tail through the bottom arches of the vertebra.

Smaller arteries, that branch in various organs into capillaries, extend from the dorsal aorta. Oxygen and nutrients penetrate through the walls of these capillaries into the tissues, and carbon dioxide and products of vital activity enter the blood. The scarlet arterial blood darkens gradually and turns into venous blood, containing much carbon dioxide and little oxygen. The venous blood is collected in the veins and is carried to the atrium.

Thus, the blood circulates continuously in a closed system.

EXCRETORY SYSTEM. Two ribbon-shaped red-brown kidneys are located in the upper part of the body cavity. Waste products, forming urine, are filtered in the capillaries of the kidneys from the blood. The urine is carried through two ureters to the urinary bladder, which opens externally behind the anal opening.

? △
1. What is the significance of the swim bladder?
2. In what ways are the respiratory organs of fishes and a lancelet structurally similar?
3. What blood circulates through the heart of a fish: venous or arterial blood?

■ Observe in an aquarium the movements of the mouth and the operculums when a fish breathes. Throw several crumbs or dry food into the aquarium. Observe how the fishes react to the food, how they grab it.

2.34 Nervous System, Sense Organs and Behaviour of Fish

SPINAL CORD. The central nervous system of fishes, as in a lancelet, is shaped like a tube. Its posterior part, the *spinal cord*, is located in the spinal canal, which is formed by the upper arches of the vertebrae. Nerves, controlling the body muscles and the fins, extend from the spinal cord to the right and left between each pair of vertebrae.

Information of stimuli is transmitted by the nerves from the sensitive cells in the fish's body to the spinal cord.

BRAIN. The anterior part of the neural tube of a fish and other vertebrates is modified into a *brain*, which is protected by the bones of the skull. The brain of vertebrates contains regions: the *forebrain*, the *diencephalon*, the *midbrain* (mesencephalon), the *cerebellum*, the *medulla oblongata*. All regions of the brain play an important role in the life of fish. For example, the cerebellum coordinates the movements and the equilibrium of the animal. The medulla oblongata gradually continues into the spinal cord. The medulla oblongata plays a great role in controlling respiration, blood circulation, digestion, and most important functions of the organism.

The sense organs make it possible for the fish to orient itself well in the environment. The eyes are very important in this sense. The perch sees only to a comparatively short distance, it discriminates the shape and colour of objects.

There are two openings, or *nares*, in front of each eye of the perch. They extend into a blind sac with sensitive cells. This is the *olfactory organ.*

The *auditory organs* are not visible on the outside, they are located on the right- and left-hand sides in the bones in the posterior part of the skull. Owing to the density of water, acoustic waves penetrate well through the bones of the skull and are perceived by the auditory organs of the fish. Experiments have shown that fishes hear the steps of a man walking along the bank, the tinkling of bells, a shot.

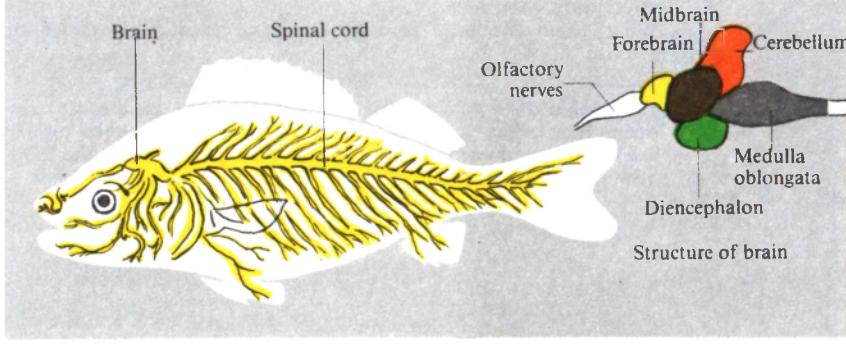


Fig. 81. Nervous system of a fish. Diagram

The *organs of taste*, represented by sensitive cells, are located not only in the oral cavity of a perch or of other fishes, but are spread also over the entire body surface. Tactile cells occur in the same places. Some fishes (for example, catfish, common carp, cod) have tactile barbels on their head.

All fish possess a special sense organ, the *lateral line*. A series of openings is visible on the outside. These openings are connected to a canal in the skin. Sensitive cells in the canal are joined to a subcutaneous nerve.

The lateral line perceives the direction and force of a water current. Thanks to the lateral line, even a blind fish will not bump into obstacles and it can catch moving prey.

REFLEXES OF FISH. Observing the behaviour of perch in an aquarium, one will see that the responses to stimulation are manifested in two ways.

If a perch is touched, it immediately rushes aside. Its response to the sight of food is just as quick. Being a greedy predator, it attacks its prey swiftly (small fishes and various invertebrates, for example, crustaceans, worms). At the sight of some prey, a signal is transmitted along the optic nerve to the central nervous system of the perch and another simulation is immediately returned by the motor nerves to the muscles of the fish. The perch swims up to the prey and grabs it. The mechanism of the organism responses to stimulation is innate, and such reflexes are called *unconditioned* ones. The unconditioned reflexes of animals of one species are similar. Being inherited, they are innate.

When the feeding of fish in an aquarium is accompanied with some actions (conditions), for example, a lamp lights up and the glass is knocked on, then after some time the signal alone attracts the fish without any additional feeding. *Conditioned reflexes* develop in the fish in response to these signals, i. e. reflexes that arise under certain conditions.

Conditioned reflexes are not inherited like instinctively unconditioned reflexes. They are individual and develop during the life of the animal.

? △

1. With the aid of Figures 75 and 81, explain the differences in the structure of the central nervous system in the lancelets and fishes.
2. What sense organs are in fish?
3. What does the complex nature of reflexes in fish consist of as compared to the reflexes of a hydra and earthworm?

2.35 Reproduction and Development of Fish

ORGANS OF REPRODUCTION. Perch, like most other fishes, is dioecious. The body cavity of females contains a large ovary, wherein egg cell (ova) develop, and males have a pair of long testes. During reproduction the testes are filled with a thick white fluid, which is *milt*. The milt contains millions of spermatozoa. The genital organs open externally by a genital opening on the abdominal side of the body.

SPAWNING. The instinct of reproduction manifests itself when the sex cells

of the fish mature. The fish migrate at this time to areas that are more favourable for the development of their young. Fish of some species migrate from seas upstream to rivers, while others, quite the contrary, leave rivers and go to the seas. The latter are so-called migratory fish. They migrate long distances in order to spawn.

The spawning migration of some salmon family (Siberian salmon, humpback salmon) in the Far East is an interesting sight: enormous shoals swim upstream, overcoming all obstacles. When they encounter rapids, they jump out of the water, while in shallow spaces they actually crawl along the bottom with their backs sticking out into the air. The fish spawn at the upper reaches and then roll down the river with the current entirely exhausted. Many of the fish perish on the way downstream. Sturgeons and some other fish species are also migratory fish, as they live permanently in the seas and return to rivers to spawn.

Eels, having a long serpentine body, inhabit freshwater bodies, and migrate from the rivers of Europe and North America to spawn in the Atlantic Ocean. Many fish reproduce in the shallow waters of their habitats.

A perch reaches sexual maturity in the second year of its life. It spawns when the ice cover melts away. A perch turns a very bright colour shortly before spawning. Perches assemble in backwaters, flood-plain lakes, and other shallow bodies without a current.

The females deposit the eggs, which are fused into bands, on aquatic plants. The males eject the milt. The motile spermatozoa swim up to the eggs and penetrate them. The complex instinctive behaviour of the fish during reproduction is called *spawning*.

DEVELOPMENT. The fertilized egg begins to divide. A multicellular embryo develops, bearing on the abdominal side a yolk sac which holds the remaining nutrients of the egg. The larva of a perch leaves the egg envelope nine to 14 days after fertilization and starts to feed independently, first on microorganisms, and later on small crustacea and other animals suspending in the water. After some time the larva gets some features resembling an adult perch, turning into a young fish. The latter grows comparatively fast:

Fig. 82. Eggs of a perch

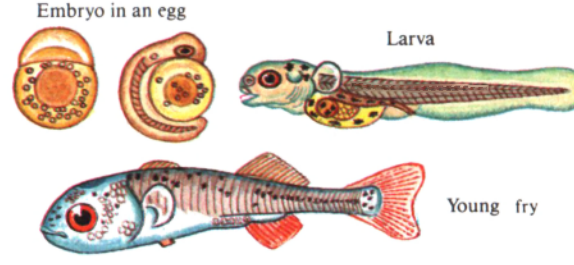


Fig. 83. Development of a common perch (magnified)

Fig. 84. Stickleback at a nest

Fig. 85. Sea horses

about two months later its length reaches 2 cm, and a one-year old young perch is about 10 cm long.

CARE OF THE YOUNG. The eggs of a perch often perish as a result of drying; or the larvae and young fish are devoured by enemies. A part of the young reach adulthood only because a perch's female lays up to 300 000 eggs. Other fish species may produce an even greater number of eggs. For example, a cod lays several million eggs.

Fish species who take care of their young usually spawn a small number of eggs, but their eggs, larvae, and young do not perish in such big numbers.

A male three-spined stickleback builds a nest of algae in the form of a muff and guards the eggs laid by the female. The male furiously attacks fishes that approach the nest by spreading its spines widely, it cleans the nest of debris, repairs it, and draws in fresh water by moving its pectoral fins. The male guards the young for several days, preventing them to swim far away from the nest.

A male sea horse does not build a nest but carries the eggs in a special abdominal brood pouch.

One African freshwater fish demonstrates still more astonishing care of its young: the male broods the eggs in its mouth and even the young hide in the father's mouth in case of danger.

? 1. Which fish are called migratory?
2. What is the significance of the number of deposited eggs?
△ 3. How do fish take care of their young?

2.36 Diversity of Fish

ADAPTATION TO ENVIRONMENTAL CONDITIONS. Fish live in the most varied aquatic habitats: in seas and freshwater bodies, at the surface and in the deep, at high and low temperatures, etc. The living conditions, food, rivals and enemies are different everywhere, which explains the great variety in the structure and behaviour of fish. Fish,

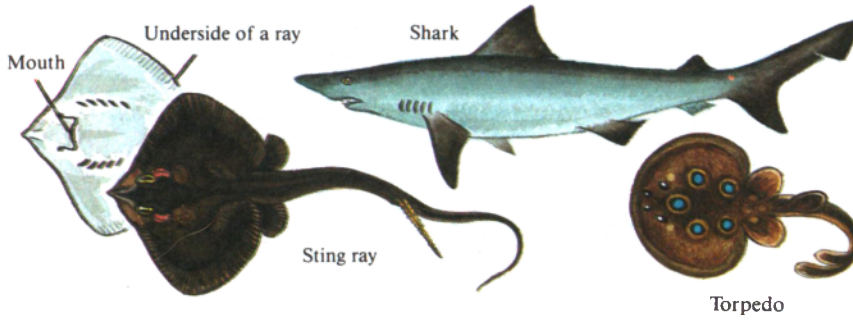


Fig. 86. Cartilaginous fish

living in the upper strata of the water and at the surface, usually have a streamlined body shape and a well-developed caudal fin, making it possible for them to swim at a high speed, when escaping from enemies, and to pursue prey. Bottom-dwelling fish, as a rule, swim slowly. Their flattened body is barely visible to prey and enemies. Fish inhabiting bright-coloured coral reefs also have a gay and bright colouration. Colourless fish inhabit water caves, where they live under conditions of entire darkness. Some deep-sea fish have luminescent organs, because sunlight never penetrates to the depth.

About 20 000 fish species are known, and we will study their major groups. All the fish are divided into *cartilaginous* and *bony* fish by the structure of the skeleton. The skeleton of the former (sharks and rays) is entirely cartilaginous (it does not ossify). They have no operculums, and the gills open externally with five-seven gill slits. They lack a swim bladder.

ORDER: BATOIDEA. Rays stay near the bottom. They swim with the aid of the anterior paired fins that edge the flattened body. The ray's tail is like a long thin whip and lacks a caudal fin. A sting ray has a long sharp tail spine. The spine is covered with poisonous mucus and the fish uses it to inflict painful wounds. A torpedo has special electric organs. The electric discharge can reach 200 volts, immobilizing prey and scaring enemies away. Rays feed on small bottom-dwelling fish, mollusks, crustacea, and other bottom dwellers.

Some rays are caught for the production of vitaminized oil.

ORDER: SELACHII. Almost all sharks are swift predators of the sea. Their jaws have sharp dagger-shaped teeth. Large sharks not infrequently attack humans. Some sharks are caught for their meat, fat, and hides.

Bony fish have a skeleton, composed of cartilage and bones. The gills of all bony fishes are covered with operculums. These fish usually have a swim bladder.

ORDER: ACIPENSERIFORMES. Unlike all other bony fish, a notochord is present not only in the embryos and larvae, but in adult sturgeons (!). The fish's body is spindle-shaped, and the anterior part of the head extends into an elongated snout. The body is not covered with an all-round scaly integumen., having instead from three to five rows of large bony plates with tiny bony grain and little plates scattered in-between.

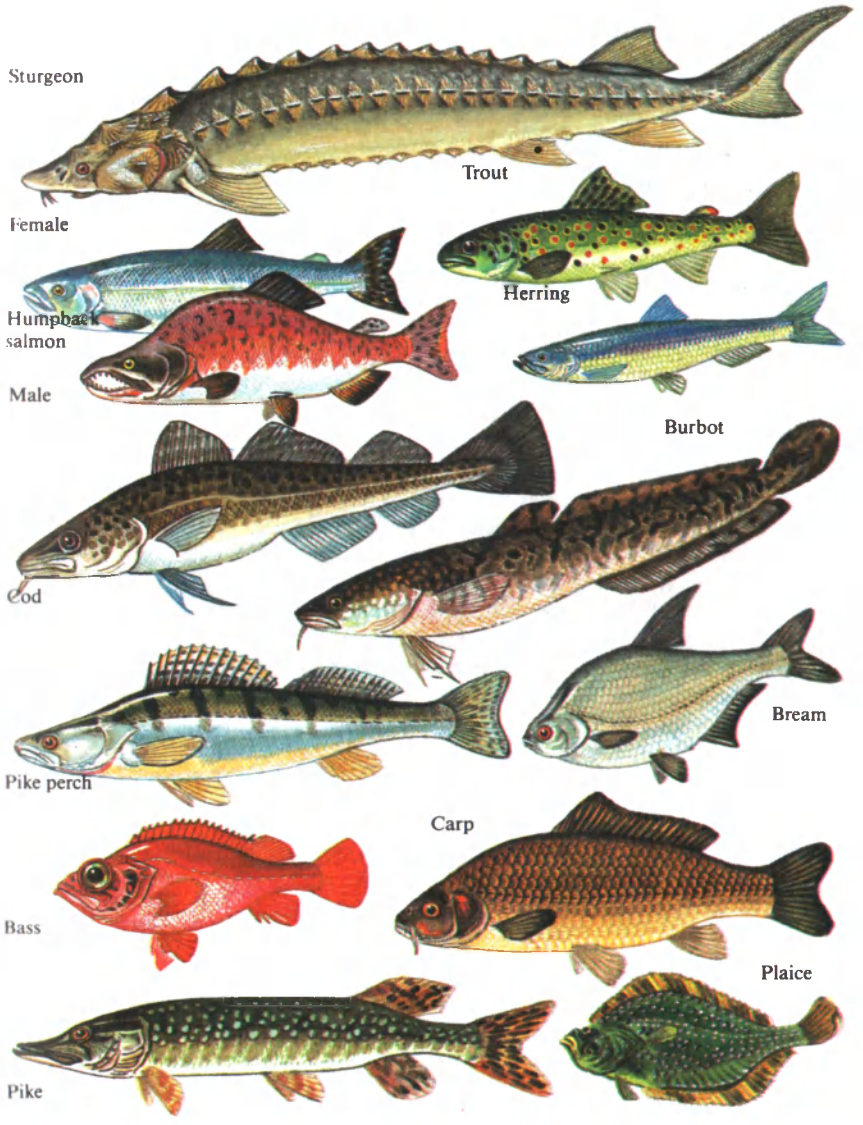


Fig. 87. Marketable fish

All sturgeons are valuable marketable fish (!). They include the common sturgeon and the Caspian sturgeon.

ORDER: CYPRINIFORMES. Carp is primarily freshwater fish, including common carp, crucian carp, roach, carpbream, and many other marketable fish.

Fig. 88. Ancient crossopterigian fish latimeria

Cypriniformes feed on vegetation and various invertebrates. Their jaws lack teeth (or they are underdeveloped), but there are pharyngeal teeth in the posterior part of the pharynx that serve to triturate the food.

ORDER: CLUPEIFORMES. The main representatives of this order are herrings. The majority of herrings occur in seas and live in vast shoals that migrate in search of food and to spawn. Herrings feed on small planctonic crustacea. This fish is of considerable marketable significance.

ORDER: CROSSOPTERYGII. Only one representative of this order, a latimeria (!), exists today. It is a big fish, whose length reaches up to 1.5 m. It inhabits the Indian Ocean near the African shores. All other coelacanths, who inhabited seas and fresh waters, became extinct 70-100 million years ago. The structure of the skeleton and the musculature of their paired fins greatly resemble the structure of the extremities of terrestrial vertebrates. However, this will be discussed later.

?
△

1. What specific features in the structure of a shark and a ray differ from that of all other fish?
2. What fish do not swallow their food whole, but first digest it?
3. Name fish species that you have seen under natural conditions. What is characteristic of their mode of life?

2.37 Economic Significance of Fish and Protection of Fish Resources

The significance of a fish in human life is exceptionally great. The total world catch of fish is about 50 million tons annually, which amounts approximately to a herd of cattle numbering 650 million heads! A greater part of the caught fish is used for nutrition. Protein is the main value of fish as a food. In addition, fish is used for the production of oil, vitamins, meal for fattening cattle. The wastes of the fish industry are used for the production of fertilizers.

The caloric value of such fish as herrings is not less than that of chicken eggs. Fish dishes are very tasty and are easily assimilated by the organism.

Fig. 89. Carp

Fig. 90. Mirror carp

Therefore, fish is a valuable nutritious and dietetic food. It is consumed in cooked, fried, smoked, salted, or canned forms. Raw fish should not be consumed under any circumstances, because one may be infected by parasitic worms.

FISHERY. Although marketable fish inhabit freshwater bodies and seas, marine species are of greater significance for fishing. These fish gather together mainly at comparatively shallow depths near continents and banks, where they find an abundance of food.

Amateur fishing is very popular. This method of fishing does not pursue economic purposes, but makes it possible for the angler to demonstrate one's skill, adroitness, and knowledge of fish biology. Fishing is a good and healthy pastime, contributing to the integrity of man and nature.

PROTECTION OF FISH RESOURCES. It would be possible to catch all the fish and prevent their future existence by applying powerful modern technology. To avoid this, measures for the protection and reproduction of fish have been taken for many years.

Laws on environmental protection and utilization of the animal world that have been adopted in all the republics of the Soviet Union, make every provision to protect fish in natural water bodies, and to enforce strict observance of the established rules of fishing. The methods and seasons for fishing are controlled by law. The nets should have meshes of a certain minimal size, so that only adult fish can be caught. It is entirely prohibited to catch fish by stunning them with explosions, because an enormous amount of fish of all ages and species perish in this case. Great attention is given to the construction of purification works that prevent the discharge of water contaminated with industrial waste into rivers, lakes and seas.

Special stepped fishways are constructed to enable the fish to pass around dams of power plants that are built across rivers. For example, salmons overcome stony rapids under natural conditions, therefore they go easily upstream via cement canals, where the water flows down from one step to another. Special mechanical fish hoists, resembling common lifts, are constructed for sturgeons.

ARTIFICIAL BREEDING OF FISH. You know now that a great amount of eggs and young fish perish under natural conditions for various reasons. The number of valuable marketable fish is increased by breeding them at special fish farms. Eggs and milt, which are stripped from adult fishes caught during

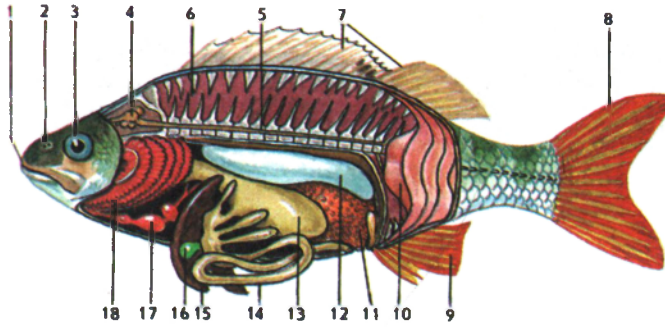


Fig. 91. Examine the drawing. Write down the names of the fish organs in the given sequence

the spawning season, are mixed and placed in water in fish-breeding apparatus. Favourable conditions for the development of the eggs are maintained in these vessels. The emerging larvae are kept in artificial ponds. When the young fish grow up and strengthen sufficiently, they are let out into natural water bodies.

The eggs and young fish can be carried over long distances by aircraft. Therefore, it has been possible to breed valuable fish species in water bodies where they had never been before. Thus, the gray mullet has been resettled from the Black Sea to the Caspian Sea. The fish has acclimatized to this new habitat and is now raised there.

POND FARMS. Some species of fish can be bred in small natural and artificial ponds from the young age to adulthood. The domesticated form of common carp, the mirror carp, is bred most frequently in artificial ponds.

The meat of a mirror carp is tastier and fatter than that of its wild ancestor, the common carp; a mirror carp grows and puts on weight faster. A wild carp is easily frightened and is cautious, while a mirror carp swims up calmly to the feeding place; it develops easily conditioned reflexes to the place and time of feeding. When breeding the mirror carp, the following features are taken into consideration: what kind of water does it live in, what does it feed on, where does it spawn, and where does it spend the winter. Man creates corresponding conditions for breeding carp.

? △
1. What is the difference between amateur fishing and fishery?
2. What legal measures are taken to protect fish resources?
3. What is the purpose of the artificial breeding of fish?

2.38 The Frog: an Aquatic and a Terrestrial Dweller

MODE OF LIFE. Frogs (!) inhabit almost the entire territory of our country, except the Far North of Siberia and high in the mountains. They live in humid areas: in swamps, damp forests, on meadows, along banks of freshwater bodies, or in the water. The behaviour of frogs is conditioned greatly by the humidity. Brown terrestrial frogs hide from the sun in dry weather, but their hunting time starts after sunset or in rainy weather. Green frogs live in water bodies or very near them, therefore they hunt in the daytime too. Frogs feed on various insects, mainly beetles and dipterans, but they also consume spiders, terrestrial and aquatic gastropods, and sometimes young fish. The frogs sit still in a secluded place when they are on the watch for prey.

Vision is of major importance for hunting. When the frog sees an insect or some other small animal, a wide sticky tongue flies out of its mouth and the prey adheres to it. Frogs catch only mobile prey.

Frogs are active only during the warm season of the year. At the beginning of autumn they hide away for the winter. They spend the winter on the bottom of water bodies, or hide in pits, burrows of rodents, under heaps of stones.

EXTERNAL STRUCTURE. A frog's body is flattened and it has a big flat head that continues into the body without distinct borders. Unlike fish, the head of amphibia is jointly attached to the body. A frog has no neck but it can turn its head to different sides and bow it.

Two large bulging eyes are protected with *eyelids*: a dermal upper one and a transparent mobile lower one. A frog winks continuously, and the moist skin of the eyelids wettens the eye surface to prevent its drying. This specific feature has developed in frogs owing to their terrestrial mode of life. Fish, whose eyes are in water all the time, have no eyelids. A pair of nares is in front of the eyes. The nares are not only olfactory organs, but a frog breathes atmospheric air that enters its organism via the nares. The eyes and nares

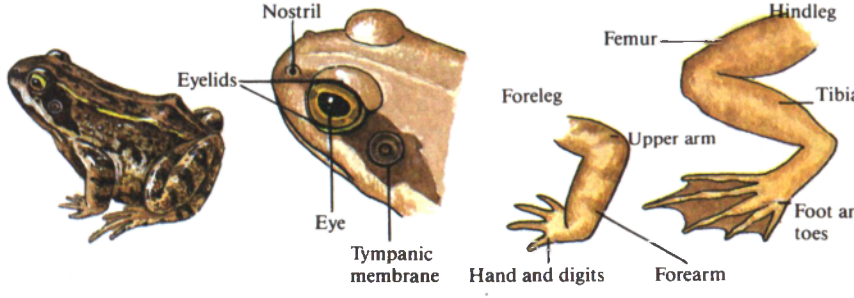


Fig. 92. External structure of a frog

are dorsally situated on the head. When a frog hides in the water, it sticks them out above the water surface. Thus, it can breathe atmospheric air and see everything all around. A little circle, covered with skin, is posterior to each eye on a frog's head. It is the external part of the auditory organ, the *tympanic membrane*. The internal ear of a frog, like that of a fish, is in the bones of the skull.

A frog has well-developed paired limbs – *front* and *hindlegs*. The former and the latter consist of three parts, which bear different names for each pair of legs. The front leg consists of an *upper arm* (humerus), a *lower arm*, and a *hand*. The hand has four digits (the fifth digit is underdeveloped). The hindleg has a *femur*, a *tibia*, and a *foot* with five toes that are interconnected by a *web*. The parts of the limbs are connected to one another by means of *joints*. The hindlegs are much longer and stronger than the front legs, and play the basic part in locomotion. A frog rests on the slightly bent front legs, while the hindlegs are folded in at the sides of the body. The frog jumps by straightening the hindlegs rapidly. The front legs protect the animal from a harsh impact against the ground. A frog swims by pulling up and straightening the hindlimbs and clasping the front legs to its body.

The skin of all modern amphibia is naked. The skin of a frog is always moist, owing to the fluid mucus that is secreted by the glands in the skin.

Water enters an organism from the environment (from water bodies, rain or dew) only through the skin, and with food. A frog never drinks water.

? 1. Which specific features in the arrangement and structure of frog's eyes are associated with an aquatic, and which with a terrestrial mode of life?

△ 2. What is the role of the front legs and hindlegs of a frog during locomotion on land and in water?

3. Talk about the life of frogs according to your summer observations.

■ Watch the behaviour of a frog or a toad in a terrarium. Put a living earthworm into the terrarium. How does the toad discover its prey, how does it sneak up to it and grasp it? Put in front of the toad a piece of meat, whose size and shape resemble an earthworm. Why does the toad leave it alone? Use a long stick to move the meat. What happens in this case? Put a frog into a basin with water and observe the movements of its hindlegs at swimming. After you have completed your observations and experiments, return the animals to their natural habitat.

2.39 The Skeleton and Musculature of a Frog

The skeleton of a frog consists of the same parts as the skeleton of a perch, but the details of a frog's skeleton are distinguished by certain differences owing to its amphibious mode of life and the development of legs.

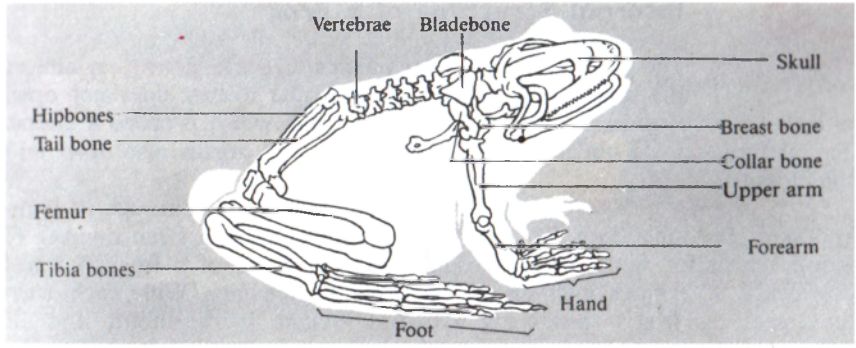


Fig. 93. Skeleton of a frog. Diagram

The vertebral column of a frog is short. Unlike a fish, a frog has a cervical vertebra. The vertebra lacks lateral outgrowths, and is flexibly jointed to the skull. It is followed by seven trunk vertebrae with lateral outgrowths (ribs have not developed in a frog). The cervical and trunk vertebrae have upper arches that protect the spinal cord. A long tail bone continues from the vertebral column in a frog and all other tailless amphibians (anurans). The tail bone is formed of several tail vertebrae that have fused together. This part of the skeleton in newts and other tailed amphibians (urodeles) consists of a large number of mobile vertebrae jointed together.

The skull of a frog has fewer bones than that of a fish. Frogs have neither gill bones, nor opercular bones, owing to pulmonary respiration.

The skeleton of the limbs is divided into three parts (see Figures 92 and 93). It is joined to the vertebral column by the bones of the limb's girdles. *The girdle of the front limbs* (*breastbone, two coracoid bones, two collar bones, and two bladebones*) embrace the trunk by a semicircle ventrally, on the sides, and partly on the dorsal side. *The girdle of the hindlimbs* (pelvic girdle) is formed by the accretion of *the pelvic or hipbones* and is still more tightly attached to the vertebral column. It serves as a support for the hindlimbs.

MUSCULATURE. The muscular system of frogs is more complicated than that of fish. A frog both swims and travels across land. By contracting certain muscles or groups of muscles, a frog can perform complex movements. The muscles of a frog's digits are particularly well developed. Unlike a fish, a frog can raise and lower its head easily.

? 1. What are the similarities in the skeletal structure of a fish and amphibians?

△ 2. What are the differences? (Use Figures 77 and 93 in your answer.)

2.40 Internal Structure of a Frog

The structure of an amphibian's digestive system is almost the same as in fish. Unlike fish, the rectum does not open directly to the outside, but into a special distension which is called a *cloaca*. The ureters and the outlet ducts of the reproductive organs also open into the cloaca.

RESPIRATORY SYSTEM. A frog breathes atmospheric air through its lungs and skin. The lungs look like sacs whose walls contain a large number of blood vessels for respiratory gas exchange. The throat of a frog contracts downward at regular intervals in rhythmic movements. With each such movement the frog is producing a partial vacuum in the mouth and air rushes via the nares and passes into the lungs. It is expelled from there by contraction of the muscles in the body walls. A frog's lungs are developed weakly and dermal respiration is just as important for the animal as pulmonary respiration. Gas exchange is possible only if the skin is moist. When a frog is placed in a dry environment, its skin dries and the animal

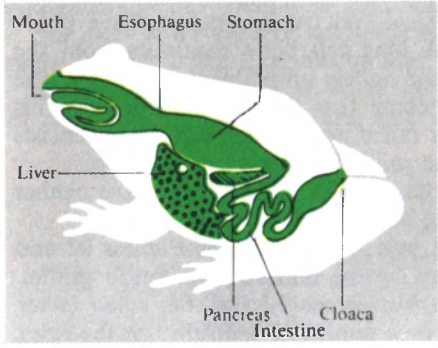


Fig. 94. Digestive system of a frog. Diagram

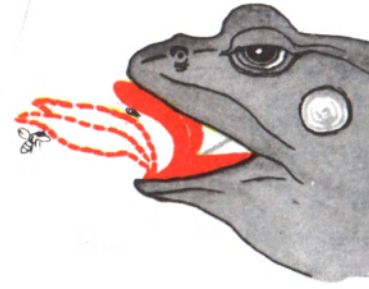


Fig. 95. Tongue movements. Diagram

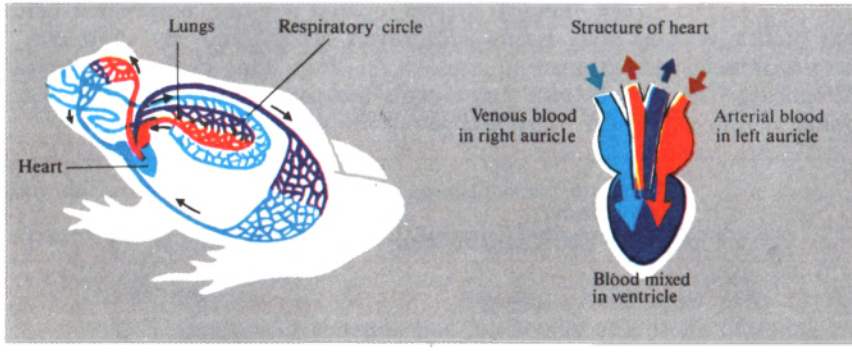


Fig. 96. Circulatory and respiratory systems of a frog. Diagram

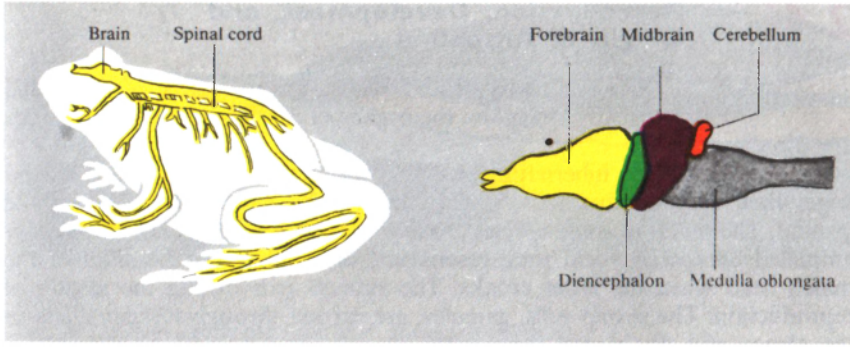


Fig. 97. Nervous system of a frog. Diagram

may perish. A frog shifts entirely to dermal respiration when it is submerged in water.

CIRCULATORY SYSTEM. A frog's heart is in the anterior part of the body under the breastbone. It consists of three chambers: a ventricle and two auricles (right and left). Both atria and the ventricle contract alternately.

The right auricle of a heart contains only venous blood, and the left one takes in only arterial blood, while the blood in the ventricle is partly mixed.

The peculiar arrangement of the vessels extending from the ventricle is the reason that only the brain of a frog is supplied with pure arterial blood, while the body receives mixed blood.

The blood is carried from the ventricle via arteries to all the organs and tissues, and is circulated via veins to the right auricle, making up the systemic circulation. Furthermore, the blood is carried from the ventricle to the lungs and the skin, and is recirculated from the lungs to the heart, i.e. to the left atrium, making up the pulmonary circulation. All vertebrates, except fish, have two circulatory circles.

Metabolism is slow in amphibia. Therefore, like that of fish, the temperature of a frog's body is almost the same as that of the environment and changes together with it.

The central nervous system of amphibia consists of the same parts as that of fish. The forebrain is more developed than in fish, and two hemispheres are distinguishable therein. Amphibia press their body to the ground and they need nothing to support equilibrium. Consequently, the cerebellum, controlling coordination of movements, is less developed than in fish.

? 1. Why doesn't a frog suffocate when it is submerged, though it has no gills?

△ 2. What is the main difference between the circulatory systems of amphibia and fish? (Use Figures 79, 80, and 96 in your answer.)

■ Observe the respiratory movements of a frog in a breeding chamber. Try to count how many times it breathes in and out a minute.

2.41 Reproduction, Development, and Origin of Amphibia

The structure of the reproductive organs of amphibia greatly resembles the organs of reproduction of fish. Frogs are dioecious.

SPAWNING. After hibernating during winter, the frogs "wake up" and begin their reproductive activity when the first warm sunbeams reach the ground. The males of some species croak loudly at this time. The sounds are amplified by special vocal sacs, resonators, that inflate on the sides of the male's head when the latter croaks. The animals pair during the season of reproduction. The sexual cells, gametes, are carried through tubular ducts to the cloaca and discharged from there.

Female amphibia deposit eggs that resemble the eggs of fish into the water. The eggs are fertilized by the male, who discharges on them a fluid, containing spermatozoa.

DEVELOPMENT. The envelope of each fertilized egg swells after some time and transforms into a jelly-like transparent layer, and the egg is visible inside it. The upper half of the egg is dark and its bottom part is light: the dark part of the egg better utilizes the sunbeams and warms up more intensely. Egg clusters of many frog species surface because the water is warmer there.

A low air temperature delays development. When the weather is warm, the egg divides many times and transforms into a multicellular larva. *Tadpoles* resembling small fish with long tail emerge from the eggs in one or two weeks. Tadpoles breathe at first through external gills which are arranged in small bundles on the sides of the head. They are soon replaced by internal gills.

A tadpole has only one circulatory circle and a two-chambered heart, the lateral line are visible on the skin (see p. 108). Thus, the larva of amphibia has some structural features in common with fish.

The tadpole feeds for several days on the nutrients stored in the egg. Then a mouth with horny jaws appears. The tadpole begins to feed on algae,

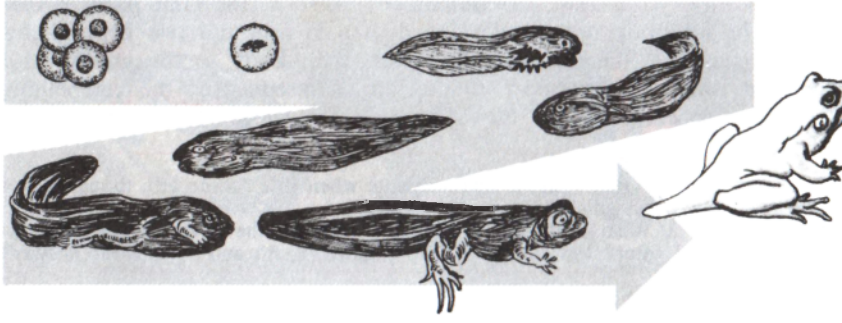


Fig. 98. Development of a frog. Diagram

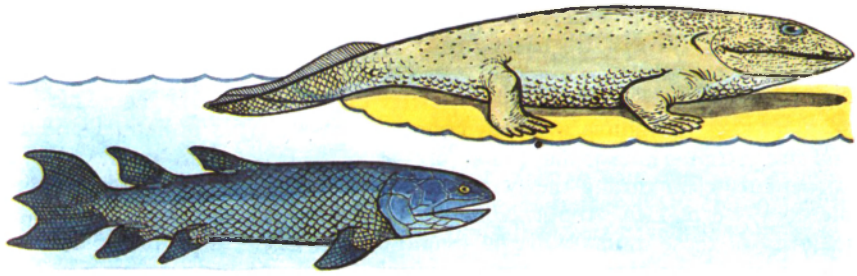


Fig. 99. Ancient crossopterigian and ancient amphibian

protozoa, and other aquatic organisms. The warmer the weather, the faster subsequent changes occur in a tadpole. The hindlegs develop first, and then the forelegs. The lungs develop simultaneously. The tadpoles begin to surface in order to breathe air. The tail shortens gradually, the tadpole transforms into a froglet and goes ashore. It takes from two to three months from the time the eggs are deposited until the tadpole transforms into a froglet. Froglets, like adult frogs, feed on animal food. They can reproduce only two years later.

ORIGIN OF AMPHIBIA. The close association of amphibia with water, and the structure and mode of life of their larvae point to the origin of these animals from fish. Fossils have been discovered of extinct amphibia. Their skin had scales, and the skull resembled that of coelacanths.

Scientists have determined that the first amphibia appeared about 300 million years ago. Their ancestors were freshwater coelacanths. A comparison of the fin's skeleton of a modern coelacanth fish, namely, latimeria, and the fossilized imprints of the fins of extinct coelacanths, with the skeleton of an amphibian's limbs indicates a great resemblance. It is presumed that extinct freshwater coelacanths had lungs that developed from the swim bladder. They inhabited shallow lakes and rivers, could crawl from one water body to another with the aid of their muscular fins. The first terrestrial vertebrates, ancient tailed amphibia, originated from these fish. Tailless amphibia appeared at a later time and they originated from ancient tailed amphibia.

Tremendous swamps covered the Earth 200 million years ago. That period was most favourable for the development of amphibia. Many of them had a length from five to six meters (the largest modern amphibian, the giant salamander, inhabiting South-East Asia, reaches a length of 1.5 m).

? 1. What is similar in the reproduction of fish and amphibia?
2. What specific features in the external structure of a tadpole make it similar to a fish?
△ 3. Talk about the development of a frog using Figure 98.
4. Why are freshwater coelacanths considered to be ancestors of amphibia, while marine are not?

2.42 The Variety of Amphibia and Their Significance

ADAPTATION TO THE ENVIRONMENT. The life of amphibia is closely connected to two types of habitat–aquatic and terrestrial. (Recall the mode of life of a frog.) This connection is particularly clear during the period of reproduction and development from the eggs (see p. 110). About 2800 species of amphibia are known, and the majority of these animals live in countries with a hot and humid climate.

ORDER: ANURA. We have studied quite in detail one representative of this order, the frog. Many other anurans inhabit our country besides the common brown, and the green frogs.

Toads (!) are quite common. They are distinguished easily by their rough and warty skin. A toad's skin secretes a caustic fluid that causes irritation when it enters the eyes or the mouth. If this happens, it is necessary to wash the affected area immediately with pure cold water. Winestales, that the skin secretion of toads causes the development of warts on human skin, are entirely groundless. The hindlimbs of toads are shorter than in frogs, and thus toads are worse jumpers. Toads are active when it is dark, and hide in various shelters in the daytime. Toads can live far away from water, owing to their well-developed lung and dry skin, but they return to the water to reproduce. They settle in gardens, fields, forests and parks and are very beneficial because they exterminate various pests of cultivated crops.

Small brown red-spotted fire-bellied toads occur in the European part of our country and in the Far East. The mucous secretion of this toad's skin is poisonous. In case of danger, the toad bends over and falls down on her back to demonstrate the bright warning coloration of her belly.

ORDER: URODELA. The members of this order are tailed amphibia (urodeles). The newt is the best known one. In spring, a wavy crest develops along the newt's back and serves to intensify dermal respiration. It is higher in the males. In summer, the newts go ashore and lead a concealed mode of life near the water body (in old stumps, pits, and other shelters). The newt's crest does not develop during the terrestrial period of its life.

Salamanders (!) live in forests on the slopes of the Carpathian Mountains

Fig. 100. European common toad

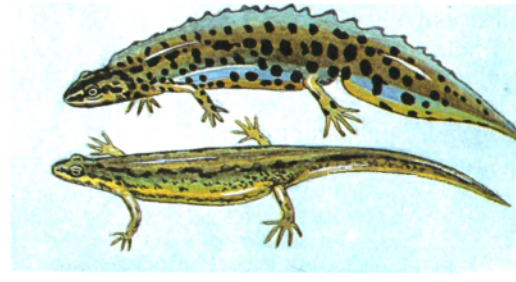


Fig. 101. Crested newts

and in the Caucasus. Like that of fire-bellied toads, their skin secretion is poisonous. Salamanders have a warning coloration; it is black with bright yellow spots.

One of the most peculiar urodeles, the olm (!), inhabits underground water bodies in some caves in Yugoslavia. Olms live in absolute darkness and, therefore, lack eyes. Olms preserve their gills for the whole life.

SIGNIFICANCE OF AMPHIBIA. The meat of large amphibia is consumed as food in many countries with a hot climate. European frogs are also quite edible, but they should be protected, owing to the great benefit they bring (as well as toads and other amphibia).

Devouring numerous insects and mollusks, amphibia exterminate pests of cultivated crops, as well as carriers of various diseases of humans and domestic animals (flies, mosquitoes, etc.).

Frogs are used on a wide scale in scientific laboratories in medical and biological experiments. They were the first vertebrates that were launched into space in March 1961 on a Soviet spaceship and then returned safely back to the Earth.

?

1. How is a frog distinguished from a toad?
2. Of what benefit are amphibia?

Class: Reptilia

2.43 Sand Lizard

MODE OF LIFE AND EXTERNAL STRUCTURE. Various lizards inhabit the entire territory of our country, except the Far North. Let's study the sand lizard, which is one of the most widespread and common species. It is a small animal, 15-20 cm in length, including the tail. The lizard lives in arid sunny areas: in steppes, forests, and mountains up to an altitude of 2.5 km. The brownish and greenish-brown coloration conceals it well amongst stones and grass. Lizards live in pairs, hiding at night in burrows, under stones, and under the bark of stumps. They hibernate in winter in the same places. Lizards feed on insects.

A lizard resembles tailed amphibia (Urodela), but it has a more slender body. The pointed head is joined to the body by a short thick *neck*. A pair of nostrils is located at the tip of the snout. Olfaction is developed better in a lizard than in amphibia. The eyes, like in all terrestrial vertebrates, are protected by eyelids. A lizard has *a third eyelid*, a semitransparent nictitating membrane, that continuously moistens the eye surface. A rounded tympanic membrane is posterior to the eyes. The audition of lizards is very sensitive: the slightest noise produced by a crawling insect attracts its attention.

From time to time the lizard flicks out of its mouth a long, thin tongue, which is forked at the tip. This is the tactile organ.

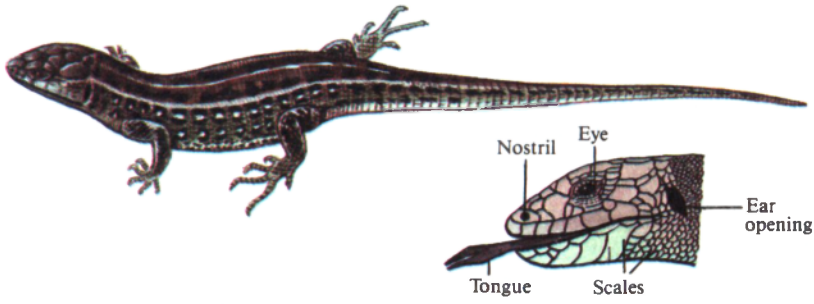


Fig. 102. External structure of a lizard

The same parts are distinguishable in the limbs of a lizard as in the limbs of a frog. Each leg has five digits with no webs in-between.

The lizard's body is covered with dry skin and epidermal *horny scales* that look like rather big plates on the snout and the belly. The horny integument forms *nails* at the tips of the digits. The lizard uses the nails to cling when climbing. The horny integument of the body prevents the animal's growth, therefore, the lizard moults four-five times during the summer: its horny skin laminates and sheds off in pieces.

The internal structure of a lizard greatly resembles that of amphibia, but there are essential differences in some systems of organs. A lizard has eight cervical vertebrae that ensure mobility of the head. A rib is joined on each side of the thoracic vertebrae. The other end of each rib is accreted by means of a cartilage to an unpaired *breastbone*. Thus, a *thoracic cage* is formed that protects the lungs and the heart of the animal.

A lizard has no dermal respiration. It breathes only with its lungs. The lungs of reptiles are more complex than those of amphibia by the increase in the number of the alveoli. This increases considerably the respiratory surface of the lungs.

The *three-chambered* heart consists of two auricles and a ventricle. Unlike an amphibian's, a lizard's ventricle has an incomplete internal partition that divides it into a right, venous part, and a left, arterial part.

Despite the greater complexity in the structure of the lungs and the heart in a lizard (as compared to those of amphibia), metabolism occurs rather slowly in its organism and depends on the ambient temperature. Therefore, lizards are active in warm weather, and become languid, like all other reptiles, when the ambient temperature drops.

The structure of the digestive, excretory, and nervous systems of a lizard resembles the respective systems of amphibia. The brains of reptiles show an advance over those of amphibia in better development of cerebral hemispheres and the appearance of cerebral cortex. The cerebellum, controlling equilibrium and coordination of movements, is better developed than in amphibia, which is associated with the greater mobility of lizards and comprehensive diversity of movements.

REPRODUCTION. When fish and amphibia breed, the eggs are laid into

the water and are fertilized there. In case of reptiles, who breed on land, the spermatozoa are introduced by the male into the cloaca of the female. The spermatozoa move along the oviduct and penetrate into the egg cells. The egg cells of reptiles are not fertilized in the water, but inside the female's organism. *Internal fertilization* is characteristic of all terrestrial animals.

A female sand lizard deposits from five to fifteen oval-shaped eggs in May-June. It buries the eggs into a shallow hole, or leaves them in the shelter where it spends the night.

The eggs of reptiles are quite large. They are oval-shaped and up to 1.5 cm long in case of a sand lizard. An egg contains an additional nutrient in the form of *yolk* to furnish food for the developing embryo. The egg is covered by a leathery shell that protects it from water loss. Unlike fish and amphibia, whose eggs produce larvae, a young lizard, resembling an adult one, hatches from a reptilian egg.

REGENERATION. Various birds, small animals, and snakes feed on lizards. If the hunting animal manages to grab the lizard by its tail, the lizard breaks off a part of its tail to save its life. Breaking off a part of the tail is a reflex response to pain, and is performed by breaking one of the vertebra in the middle. The muscles around the wound contract and there is no bleeding. The tail grows again, it regenerates.

? 1. What is the difference in the structure of the limbs of a lizard and a frog?

△ 2. In what ways is the structure of the lungs and heart of a lizard more complex than the structure of the lungs and heart of a frog?

3. How can the difference between the structure of a frog's egg and a lizard's egg be explained?

■ Watch the movements of a lizard in a terrarium. When does it flick out its tongue? Put some living food into the terrarium. See how and with what does a lizard grab its prey.

2.44 The Variety of Modern Reptiles

ADAPTATION TO LIVING CONDITIONS. The majority of reptiles are typical terrestrial animals. Unlike amphibia, they have well-developed lungs, but no dermal respiration and, therefore, they do not need regular moistening of the skin. Reptiles do not breed in water, they breed on land. Therefore they frequently settle far away from water bodies. Some reptiles lived in water (for example, crocodiles, marine and freshwater turtles), but they resettled to aquatic conditions only after they had adapted to terrestrial life. All aquatic reptiles breathe only atmospheric air, and breed on land, where they deposit eggs.

About 7000 species of modern reptiles are known, and numerous fossils of ancient, long extinct representatives of this class have been discovered. You will learn the main orders of modern and extinct reptiles.

Fig. 103. Slow-worm

ORDER: SQUAMATA. The name of this order (*squamate* means *scaly*) indicates that the bodies of the representatives of this order (lizards and snakes) are covered with scales.

Many other species are known besides the sand lizard. The viviparous lizard does not lay eggs because the young are born alive after hatching inside the mother's body.

Everyone knows about snakes, and many have seen them under natural conditions, or at a zoo. Nevertheless, it is not so easy to distinguish a snake from a lizard since there are legless lizards (for example, the slow-worm in the USSR), who are often confused for snakes. An important external feature of snakes is the structure of the eyelids: they are fused together, become transparent, and cover the eyes like a watch crystal. Hence, the strange, unblinking stare of a snake gave rise to absurd ideas of their supposedly hypnotic power. Lizards (including legless ones) have mobile opaque eyelids.

When a snake sheds its skin, the latter comes off in one piece, turning inside out like a stocking. Superstitious people ascribe miraculous properties to the shedded skin.

Snakes move forward by coiling up and lunging their body forward (*reptile* in Latin means *crawl*). Hence, the name of the class: Reptilia–Crawler.

Fig. 104. Grass snake

Fig. 105. Reticulated python

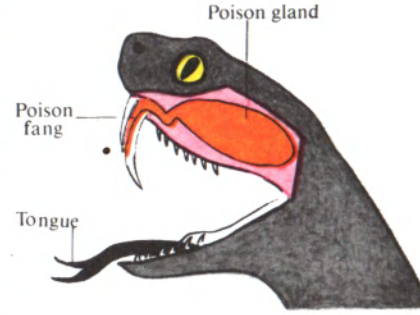


Fig. 106. Poisonous equipment of a snake

The majority of snakes deposits eggs. The common viper, which occurs in the USSR, is a viviparous snake.

All snakes swallow their prey whole. The bones of the jaws are joined by ligamentous connections and are mobile, while the teeth are angled backward. It seems as though the snake pulls its head over the prey's body, like putting a glove on one's hand.

Some snakes swallow their prey alive, such as grass snakes, living near water bodies or in the water, which swallow frogs and fish.

A boa constrictor first strangles its prey by coiling its body around the latter. Little boas (less than one metre long) occur in the deserts of Kazakhstan, Soviet Central Asia, and in the Caucasus. They attack jerboas and other little desert dwellers. Tremendous boas inhabit tropical countries. The largest snake is the giant anaconda, reaching up to 11 m in length. It lives in South America.

The toxicity of snakes is well known, though poisonous snakes make up only one tenth of the total number of their species. The poison glands are in the snake's head behind the eyes (they are modified salivary glands). These glands produce strong poison.

The tubular fangs, in the anterior part of the upper jaw of venomous snakes, are connected with the poison gland. The fangs are used to inject

Fig. 107. Grecian tortoise

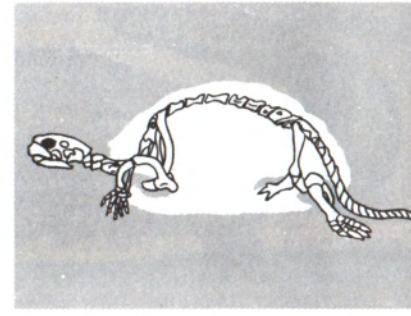


Fig. 108. Skeleton of a turtle. Diagram

poison into the organism of a prey or an enemy when biting it. The so-called "sting", a long tongue that is forked at the tip, is not at all related to the poison equipment. The tongue is simply an organ of touch and taste, which is similar in all snakes–poisonous and nonpoisonous. A snake sticks out its tongue continuously to touch the surrounding objects, feeling and "tasting" them.

Self-treatment should not be administered if one is bitten by a snake (to make cuts, or cauterize, or put on compressing bandages, etc.). The victim should be taken to a physician as fast as possible. It is most effective to inject a special antivenin and thus to perform a blood transfusion. If bitten by a viper it is advisable to drink hot tea, or coffee.

Snakes, even poisonous ones, should not be killed. Poisonous snakes, occurring in the USSR, don't attack people, but they bite if they are teased or trodden upon.

All snakes, including poisonous ones, are beneficial for exterminating harmful rodents. The poison of snakes is used in medicine in various drugs. To this end, snakes are kept at special farms.

ORDER CHELONIA. The body of a turtle is covered with a carapace, which is formed by the expanded bones of the skeleton and is covered with horny scales. In case of danger, the turtle retracts its head, limbs and tail into the carapace, or conceals them under its edges. Now they are well-protected against enemies, because the carapace is very strong. Turtles lack true teeth and have a horny beak covering their jaws. Terrestrial tortoises have a high-arched carapace and short digits. Aquatic turtles carry a flattened carapace. Turtles inhabiting lakes and rivers have a webbed digits, and the limbs of marine turtles have become modified into paddle-like flippers.

Terrestrial tortoises inhabit the southern regions of Kazakhstan and the territory of Soviet Central Asia. In spring they wander across the deserts and the steppe, feed on the juicy parts of plants, and deposit eggs. At the beginning of summer, when the vegetation fades in the sun, the turtles dig burrows and go into summer hibernation. They wake up in autumn to feed on the meagre autumnal vegetation, and then return to the burrows for the whole winter.

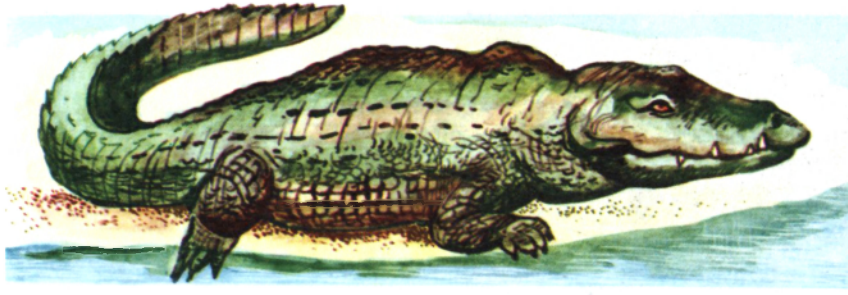


Fig. 109. Crocodile

ORDER: CROCODILIA. Many years ago crocodiles inhabited water basins throughout the tropical regions of all the continents worldwide (mainly in South America, Africa, and Asia). Many of these animals were killed since they were hunted for their beautiful and strong leather hides.

Crocodiles externally resemble giant lizards, reaching a length up to 10 m. The tail of the animal is quite flattened on the sides, which is due to their aquatic mode of life. Crocodiles have the most complex structure of all other modern reptiles. In particular, the lungs of crocodiles have many septa inside, and, unlike all other reptiles, their heart is a *four-chambered* one, though the venous and arterial blood mix partially on discharging from the heart.

Crocodiles watch for prey submerged in the water, with only their eyes and the tip of their snout with the nostrils above the water surface. Young crocodiles feed on fish, amphibia, birds, while large adults are capable of overpowering big beasts who come to drink water.

?
1. What is the benefit of poisonous snakes?
2. What specific features in the structure and behaviour of snakes have given rise to superstitions?

△
3. How is an aquatic turtle distinguished from a terrestrial one by its appearance?
4. List briefly the characteristics of the orders of reptiles. What features unite them all into one class?

■ Observe the movements of a turtle in the nature corner of your school. Feed the turtle cabbage leaves, sliced carrots or apples. Watch how it takes the food. How does it hold a cabbage leaf or the leaf of some other plant? Give the turtle a saucer with water. How does it drink? Touch the turtle's head with your finger and see how it conceals its head, limbs and tail under the carapace.

2.45 Extinct Reptiles

ORIGIN OF REPTILES. When comparing the structure of amphibia and reptiles, it is easy to discover a great resemblance between these classes of vertebrates. Excavations have led to the discovery of skeletons of very ancient reptiles, whose vertebral column had a short neck (like in amphibia), and the breastbone was absent. Hence, they had no true thoracic cage. This means that the first reptiles originated from ancient amphibia. Scientists established that reptiles appeared about 250 million years ago. They settled in places that were inaccessible to amphibia owing to their ability to adapt to living conditions far away from water.

ORDER: DINOSAURIA. The term *Dinosauria* means *terrible lizard* and refers to extinct terrestrial reptiles, whose skeletons and bones are discovered at excavations. Some dinosaurs reached tremendous sizes. For example, the

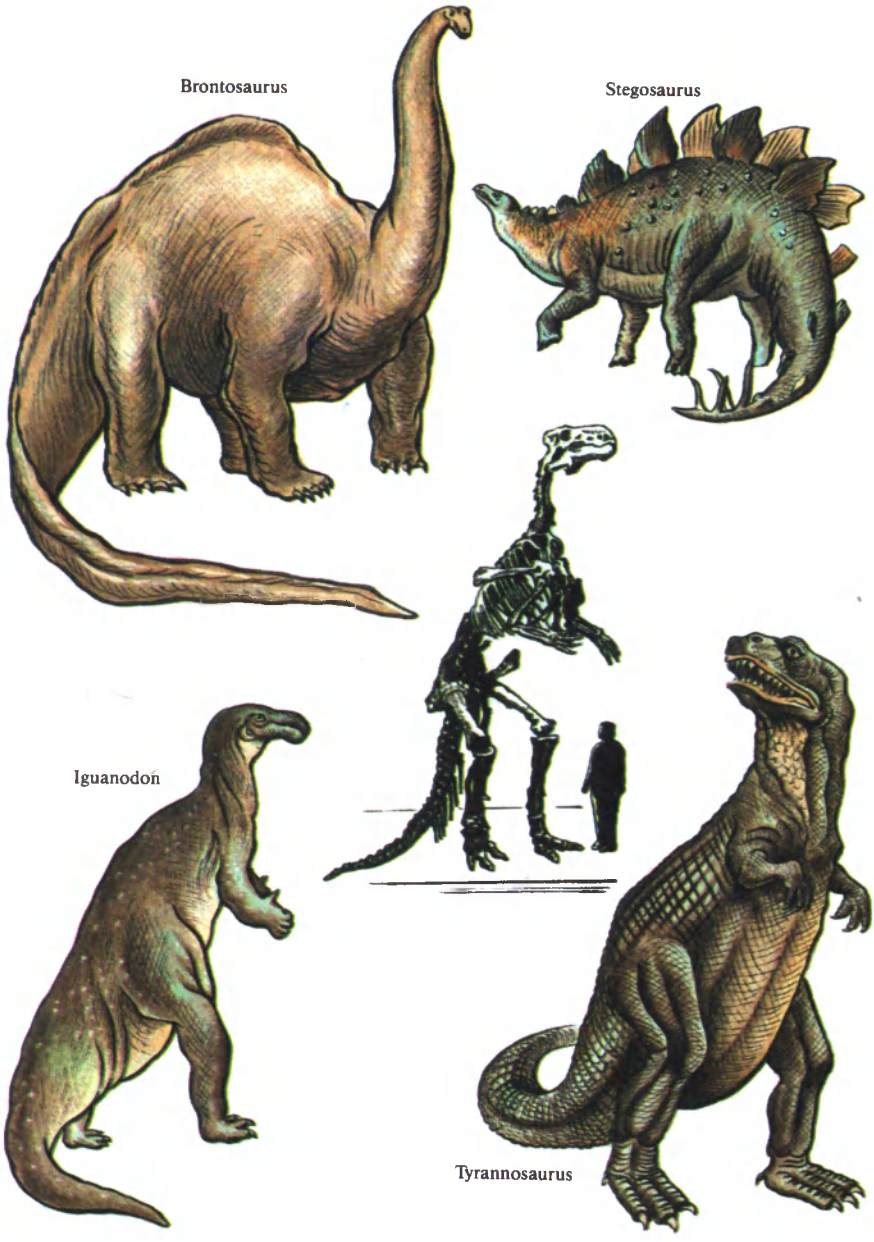


Fig. 110. Extinct reptiles

body length of a herbivorous brontosaurus reached 18 m. It had a little head, a long thick neck, and a powerful tail. Diplodocuses, who resembled brontosaurus, were still larger (up to 27 m). There existed carnivorous dinosaurs, for example, the tyrannosaurus. They ran rapidly on strong hind-legs and, overtaking their prey, tore it to pieces with their strong teeth. Some herbivorous dinosaurs had horns, spines, and horny outgrowths on their body that served for defense against enemies. One such extinct giant (stegosaurus) is shown in Figure 110. Besides gigantic dinosaurs, there were also many small ones.

ORDER SAURISCHIA. Teeth in these reptiles were divided into incisors, canines, and molars. Unlike modern reptiles, the limbs of the saurischians were under the body, rather than sprawled out to the sides. Later, we shall return again to these specific features of saurischians when speaking about the origin of mammals.

EXTINCTION OF ANCIENT REPTILES. There were many other reptiles, who had an astonishing appearance, size and mode of life.

The number of their species totalled more than all the species of modern terrestrial vertebrates. The majority of reptiles became extinct, and those that have survived make up a negligible part of the bygone number. The extinction of reptiles occurred about 70–90 million years ago. Why did they become extinct? The reasons lie not only in a change of climate: the hot climate was replaced by a cold climate. A drop in temperature is not very threatening for animals who can hibernate. It is important to note that the extinction of reptiles coincided in time with the flourishing of birds and mammals. Evidently, the major role in the extinction of ancient reptiles belonged to the rivalry of the more perfect terrestrial vertebrates: birds and mammals.

? △
1. When did the first reptiles appear? Whom did they evolve from?
2. Where did various representatives of dinosaurs live and what did they feed on?
3. List briefly the characteristics of the classes of fish, amphibia, and reptiles. Compare your lists. Which of these classes is more highly organized? What features can you cite to prove this?

Class: Aves (Birds)

2.46 External Structure of Birds

MODE OF LIFE AND EXTERNAL STRUCTURE OF A PIGEON. Let's examine the structure of birds using a pigeon as an example. They live in towns and villages, stay in flocks, settle in man-made pigeon-houses. Pigeons feed on seeds and the green parts of herbaceous plants, as well as on bread and food remains that are fed to them by people.

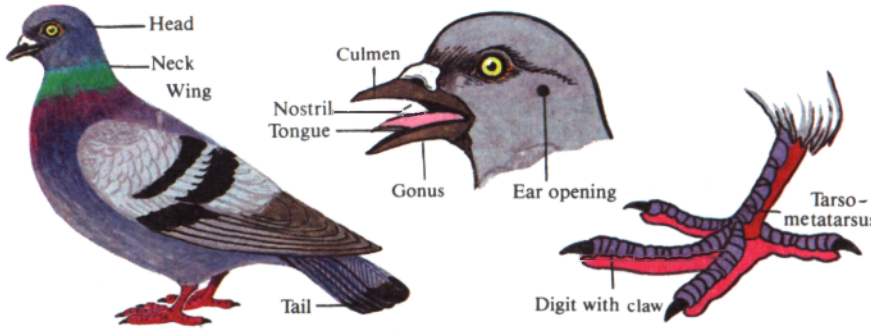


Fig. 111. External structure of a pigeon. Diagram

The body of a pigeon is divided into the same parts as that of reptiles: a head, a neck, a body, and limbs.

The head of a pigeon is small, rounded, with quite a long, thin extensile *bill* with a horny covering. The bill consists of two parts: an upper – *culmen*, and a bottom – *gonus*. Nares open at the base of the culmen. Big round eyes are on the sides of the head, and ear openings are concealed under feathers slightly below and behind the eyes.

The pigeon's head is supported on an extremely mobile neck, enabling the bird to peck food adroitly, look around, and use the bill to clean the feathers on the abdomen, wings, back, and tail.

The forelimbs, *the wings*, serve for flying.

A pigeon walks on the digits of the hindlimbs, the feet. The lower part of the feet and the digits are covered with rough skin and horny scales.

A flying bird greatly resembles an aircraft. It has a fuselage – a body, carrying planes – wings, a rudder – a tail, a carriage retractable in flight – feet. The main work in flight is done by the wings. These features form the carrying surface of the wing. They form the plane that supports the airborne bird.

BODY COVERINGS. The skin of birds is dry, thin, and covered with *feathers*. The feather covering is a characteristic external feature, distinguishing birds from all other animals.

The *contour feather* contains a narrow firm *rachis* or shaft, and wide, softer *vanes* on its sides. The base of the rachis, the *calamus* or quill, is like a semitransparent cylinder. The vanes of the feather are formed by a thick network of thin *horny barbs*, branching off the rachis. Barbs are attached to the rachis parallel to each other. Thin barbules branch off from each barb on both sides, interlocking with the adjacent ones and attaching to them by means of microscopic hooks. This structure of a feather makes it flexible, light, and almost impenetrable to air.

The covering contour feathers, overlapping one another with their tips like tiles on a roof, form a continuous, smooth, streamlined surface that facilitates flight. The large contour feathers of the wings (the flight feathers) and tail (rectrices) are of major significance in flight.

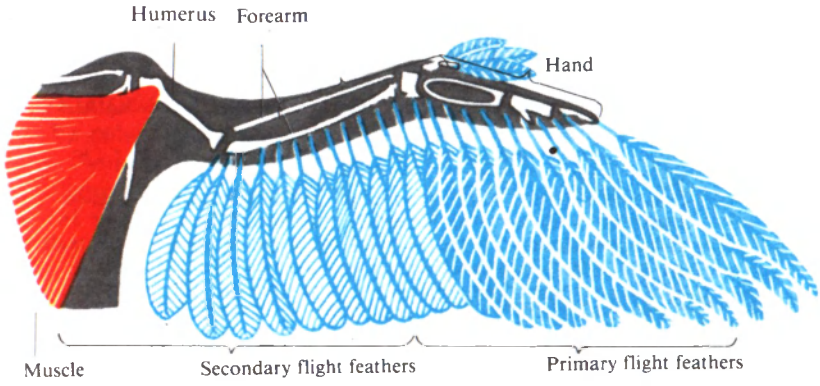


Fig. 112. Wing of a pigeon. Arrangement of flight feathers. Overlapping feathers are removed. Diagram

Small *down feathers* are under the overlapping contour feathers. Their vanes are soft, loose, without barbules. Some birds also have *down* proper, which is a short rod with a bunch of barbs at the tip in the form of a brush.

The feathers, and especially the down ones and the down proper keep the bird's body warm. There is a lot of air between their barbs, in the rachises, and in the down proper, and air is characterized by poor heat conductivity.

Birds periodically molt: the worn feathers fall out and new ones grow in their place.

Only the preen gland on the dorsal side at the base of the tail is developed. The bird uses its bill to press out drops of oily fluid from the gland, which it then spreads on the feathers, making the latter elastic and resilient, and in waterfowl the feathers are thus protected against water.

The feathers, down, horny coverings of the bill and feet, as well as the claws of birds are formed of the upper layers of the skin. The horny skin on the feet, which consists of small scales or plates fitting closely to one another, resembles the scaly integument of reptiles.

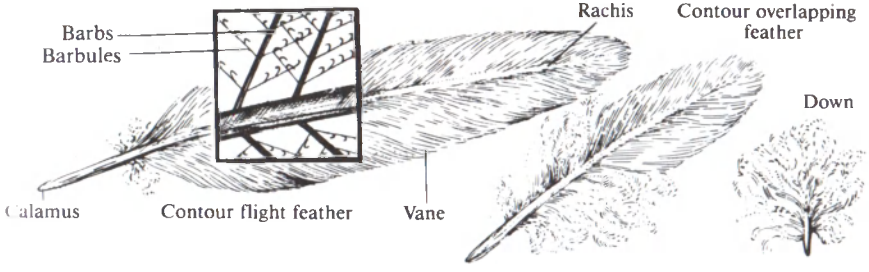


Fig. 113. Feathers and down of a bird. In square to the left – magnified part of a contour wing. Diagram

? 1. What specific features in the external structure of birds make them close to reptiles? What features of birds distinguish them from reptiles?

△ 2. What is the importance of the contour feathers, down feathers and down proper?

3. How do birds take care of their plumage?

■ Examine different feathers with the aid of a magnifying glass. Pay attention to the way the barbs are interlocked in a contour feather. Tousle the vane with the aid of a preparation needle and examine the hooks in a microscope. Pull the tousled contour feather through tightly compressed fingers. Make sure that all the barbs fall into places easily and exactly, and that the feather looks like it did before.

2.47 Skeleton and Musculature of Birds

The skeleton of birds consists of the same main parts as the skeleton of reptiles. A rounded skull, containing the brain, very big eye sockets, toothless upper and lower mandibles, making up the bony base of the bill, are distinguished in the skull. All the bones of the skull are thin, light, and tightly accreted together.

The vertebral column consists of a large number of vertebrae that are grouped into five sections. Numerous (up to 25) cervical vertebrae are jointly articulated to one another, making the neck very flexible.

The thoracic vertebrae are almost immobile, the lumbar and sacral ones are accreted together and reliably support the body. This is very important for flight.

Several posterior, tail vertebrae in birds fuse into one pygostyle, which is the base to which the retrices are attached.

The vertebral column, ribs, and wide breastbone, the *sternum*, that resembles a boat, form the thoracic cage in birds. A *keel*, which is a high ridge, is on the underside of the sternum.

Ribs are attached to the thoracic vertebrae. A bird's rib consists of two parts. Its upper part is joined to the vertebral column, and the bottom part is connected to the sternum. Both parts of the rib are jointed to one another at a certain angle. A small outgrowth, overlapping the neighbouring rib, extends from the upper part of each rib, thereby providing the thoracic cage with additional strength for preserving the sternum's mobility.

The girdle of the forelimbs (the pectoral girdle) in birds is made up of three paired bones: the coracoid bone, bladebone, and collar bones. The lower ends of the collar bones are accreted and form a fork. The skeleton of a bird's wing consists of one humerus, two bones of the forearm, namely, the *ulna* and the *radius*, and several bones of the hand.

Unlike the pentadactyl forelimb that is characteristic of the majority of amphibia and reptiles, the forelimb of a bird, the wing, contains only three

digits. The several small bones of the hand are fused into one carpometacarpus. The reduced number of digits, and fusion of the small bones in the hand ensure strength in this part of the wing that carries the greatest load in flight.

The pelvic girdle consists of three pairs of bones that fuse into a whole with the lumbar and sacral parts of the vertebral column and the first tail vertebrae. The pits of the joints are on its sides, and the hindlimbs are joined to the pits.

The foot contains quite a thick femur, a thinner and longer tibiotarsus, consisting of two accreted bones, a tarsometatarsus, and digits. The *tarsometatarsus* or simple tarsus is characteristic only of birds. It contains several small bones of the foot that fused into one bone. The bones of the digits are joined to the lower end of the tarsometatarsus. A pigeon, like almost all other birds, has four digits. One digit is turned backward, three face forward.

The majority of bones in a bird are hollow, they contain air and, therefore, are very light.

MUSCULATURE. The paired *major pectoral muscles* are the largest muscles in the body of all flying birds. Their mass is the same as the total mass of all the other muscles. These muscles extend from the pectoral bone and its keel,

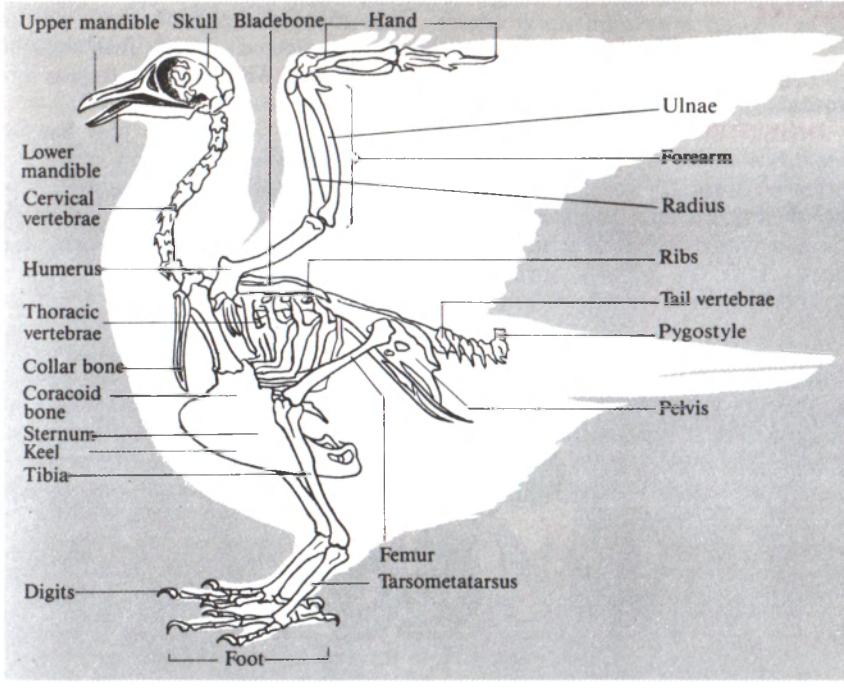


Fig. 114. Skeleton of a pigeon. Diagram

and end on the humerus. These muscles are the ones most used in flight.

These most powerful muscles of a bird are attached to the lateral surfaces of the keel. The weaker *subclavicular muscles* under the large pectoral ones lift the wings. Intercostal muscles, that ensure a change of the thoracic cage volume during respiration of the bird, are attached to the ribs and their outgrowths.

The muscles of the neck and feet are well developed in a pigeon. The muscles of the neck participate in the movements of the head: for turning, lifting and lowering it. The muscles of the feet are best developed in birds that inhabit the steppe and deserts, who walk and run a lot, for example, ostriches and bustards.

? 1. What is the main difference between the skeletons of a bird, an amphibian, and a reptile? (Use Figures 93 and 114 in your answer.)
△ 2. Use Figure 114 and tell us the names of bones in the skeleton of a bird's wing.
3. What muscles are most developed in flying birds?
4. What is the keel on the breastbone (sternum) needed for?

2.48 Internal Organs of Birds

The body cavity of birds is protected almost fully by the thoracic cage and the wide pelvis. The internal organs are contained in the body cavity.

DIGESTIVE ORGANS. Let's open the beak of a pigeon: the bird has no teeth but we see a short tongue with a sharp horny tip. A pigeon and many other birds use the tongue only to transfer the food deeper into the mouth to the pharynx. The food slides from the pharynx into the esophagus. In many birds a distensible *crop* is in the lower end of the esophagus level with the neck's base. A pigeon's crop is very big. The swallowed food is stored temporarily in the crop, where it is moistened and softened by the secretions

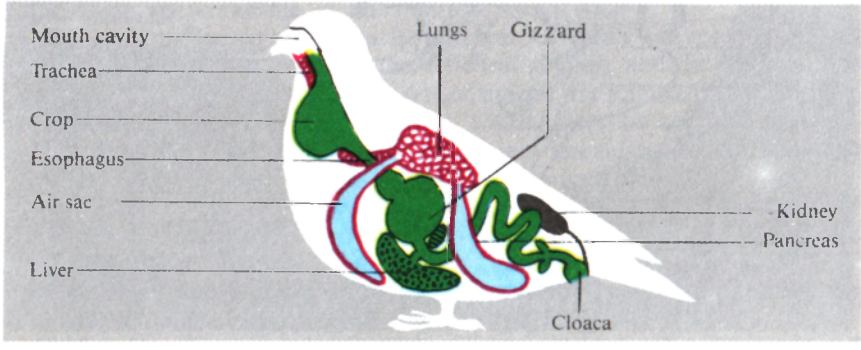


Fig. 115. Digestive, respiratory and excretory systems of a bird. Diagram

of the glands. The swollen seeds are transferred from the crop through the esophagus further into the stomach.

The stomach of birds is divided into two chambers: the anterior glandular *proventriculus* and the posterior muscular *gizzard*. The food is treated in the glandular proventriculus by the digestive juices.

Strong muscles are well developed in the walls of the muscular gizzard. The internal surface of this chamber in a pigeon and other seed-eating birds is covered with a folded horny lining. Contractions of the muscular walls of the gizzard cause movement and aid in grinding the food against the horny walls and small stones that these birds constantly ingest. As a result, the seeds and other food are ground and transformed into a soft pulp.

Digestion in pigeon, as in other seed-eating birds, continues for two to three hours, and it is still faster in insectivorous birds.

Like in the case of amphibia and reptiles, the rectum of birds ends with a distension, a *cloaca*. The ureters and the outlet ducts of the reproductive organs also open into the cloaca.

Most birds eat very much, feeding almost the whole day long. Their life passes in perpetual motion, in continuous activity. To this end, they spend much energy that demands replenishment, therefore the organism of birds requires a nourishing diet.

Rapid digestion and frequent removal of waste from the intestine frees a bird from unnecessary loads. Low weight is an important condition for successful flight.

RESPIRATORY ORGANS. If you open a pigeon's mouth wide, you will see the glottis behind the tongue. It opens into the larynx that continues to the

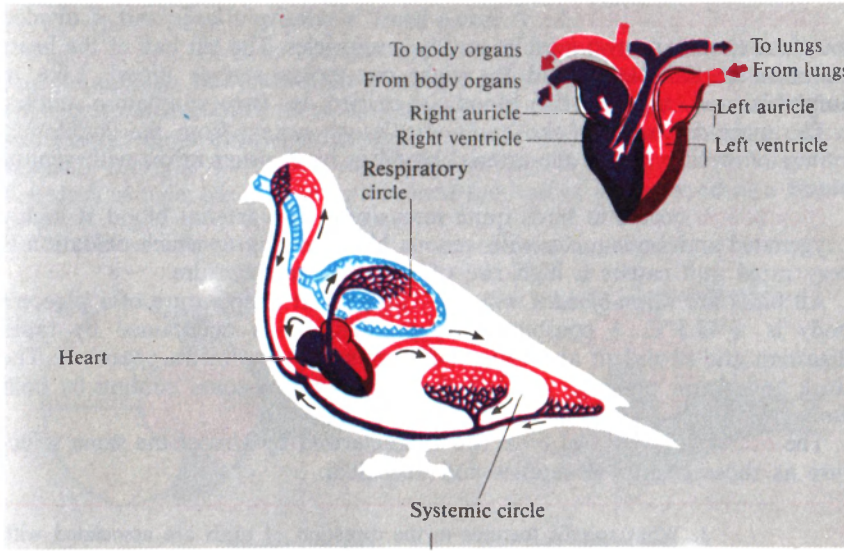


Fig. 116. Circulatory system of a bird. Diagram

windpipe, the trachea. The trachea is arranged along the whole neck of the bird anterior to the gullet (esophagus). The vocal organ, the syrinx, owing to which birds can produce various sounds and sing, is at the lower part of the trachea. Where it enters the body cavity, the trachea branches in two bronchi that are extended into the lungs.

The lungs of birds differ by structure from the sac-like lungs of amphibia and the alveolar lungs of reptiles. Thin branching bronchi and blood capillaries intertwine densely in the lung tissue of birds, ensuring intensive gas exchange between the blood and atmospheric air.

A part of the bronchial branches pass through the lungs and form thin-walled *air sacs* outside the latter. The sacs are located in various parts of the bird's body, for example, between the internal organs, between the muscles, subcutaneously, and even inside the tubular bones of the skeleton. When a bird is not in flight and walks on the ground or sits on a branch, inspiration and expiration occur by lowering and raising the sternum. The volume of the thoracic cage increases when the sternum is lowered, and the air flows to the lungs through the respiratory pathways. The air is expired when the sternum is lifted.

The sternum is immobile during flight as the entire thoracic cage is a support for contraction of the strong pectoral muscles, and respiration occurs on account of lowering and lifting the wings. When the wings lift, the air sacs expand and air penetrates into them by flowing through the lungs. As the wings lower, the air sacs compress and discharge fresh air into the lungs. Thus, gas exchange occurs in a flying bird during both inspiration and expiration. Double respiration ensures continuous ventilation of the lungs with fresh air.

CIRCULATORY ORGANS. A bird's heart is relatively large and is divided into four chambers: two auricles and two ventricles. The left half of the heart contains arterial blood, and the right one holds venous blood. Like in amphibia and reptiles, the blood is carried in two circulation circles.

The main difference of the bird's circulatory system from the circulatory system of reptiles is that the arterial blood in birds never mixes with venous blood.

Metabolism occurs in birds quite intensively. The arterial blood is highly oxygenated and never mixes with venous blood, owing to which oxidation is very rapid and causes a high rise of the body temperature.

All birds are *warm-blooded animals.* The normal temperature of a pigeon's body is $+43.5\,^{\circ}C$. A constant body temperature is maintained by rapid digestion and abundant absorption of nutrients by the bird's organism. The thick and warm plumage protects the bird's body against cooling by cold ambient air.

The excretory organs of birds are characterized by almost the same structure as those organs in reptiles and amphibia.

?

1. What specific features in the digestion of birds are associated with flight?
2. What does the process of double respiration consist of?

△ 3. What is the main differences between the bird's circulatory system and that of reptiles?
4. Speak about the feeding habits of various birds you know on the basis of your summer observations.

2.49 Nervous System, Sense Organs, and Behaviour of Birds

BRAIN. As compared to fish, amphibia and reptiles, the brain is more developed in birds, especially the hemispheres of the forebrain and the cerebellum. The development of the cerebral hemispheres is associated with the very complex behaviour of birds. As is known, the cerebellum ensures equilibrium and controls coordinations of movements. The role of the cerebellum is very great in birds, capable of flight and performing complicated and various movements.

SENSE ORGANS. Birds have keen vision. For example, an eagle, hovering high in the skies over a meadow, sees a mouse running around in the grass. The majority of birds have wide-range and almost circular vision. Therefore, birds see forwardly, sideways and partly behind themselves.

The eyes of birds, as those of reptiles, have three eyelids: upper, lower, and a transparent internal one, a nictitating membrane.

The hearing of birds is very keen. They perceive even the slightest noise that warns them of danger. Many nocturnal birds of prey hunt in the darkness by using their sense of hearing. A young bird begins to sing, imitating the singing of adults, and this requires a very good ear for music.

The sense of smell is poorly developed in birds.

The behaviour of birds is more diverse and complicated than the behaviour of amphibia and reptiles. Birds choose a convenient place for a nest, find appropriate material for its construction, build the nest, hatch nestlings, feed and protect them from enemies. All these activities are instinctive in birds. Instincts combine with new conditioned reflexes in nestlings from the very first days of their life. The unconditioned food reflex is displayed in a hatch-

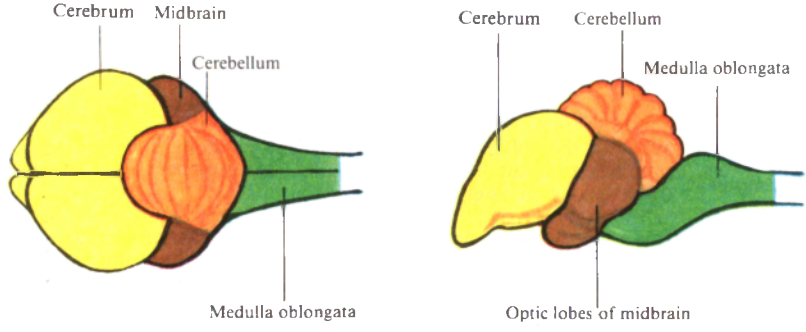


Fig. 117. Brain of a bird. Diagram

ing in pecking. At first it pecks all the objects it sees. Gradually, from its own experience, the chick begins to discriminate edible from inedible and rarely make mistakes thereafter.

Birds gradually gain more and more conditioned reflexes. Chicks recognize well the voice of the one who feeds them, orient well in the environment outside the poultry-yard, distinguishing it from other buildings. Undoubtedly, old birds possess advantages over young ones owing to their accumulated life experience. Birds are capable of borrowing this experience, thereby making their life easier. Communication is well-developed among birds. Besides singing, birds produce many different sound signals indicating anxiety, fright, calls, warning of danger, causing a respective response from individuals of their species.

Knowing this "language" of birds, which is different for each species, a man can make use of tape-recorded warning cries of birds to frighten them away. For example, this is done when it is necessary to frighten flocks of sea gulls from the runways of an aerodrome, or starlings from a vineyard.

Birds have developed a special sense of orientation in space. If an adult bird is caught and carried dozens of miles away from its nest where its nestlings are, and then it is let free, the bird unerringly finds its way back. This phenomenon is the basis of pigeon-post. Leaving for a long-distance journey, men took pigeons along with them. The pigeons, returning back to the pigeon-house, brought news about the travellers. The sense of orientation is of great significance during the migration of birds.

Many birds can be trained because they develop conditioned reflexes quite easily and rapidly. Crows, rooks, starlings are trained easily. Trained parrots are well-known because they can be taught to repeat individual words and even some small sentences.

One may be sure that talking parrots don't put any sense into their speech, and their behaviour in this case should be considered as a conditioned reflex. However, conditioned reflexes in birds are more diverse and complicated than in reptiles, amphibia, and fish.

The interweaving of unconditioned and conditioned reflexes distinguishes the behaviour of birds from the behaviour of amphibia and reptiles. This combination makes it possible for birds to adapt well to changing environmental conditions.

△ ?

1. Use Figure 117 and discuss the especially well-developed parts of a bird's brain. What is this associated with?
2. What is the difference of bird's behaviour from the behaviour of reptiles and amphibia? (Use the material of your summer observations in your answer.)

■

Put a piece of pork fat outside the window in winter (the fat should not be salted because salt is bad for birds). See how the birds take notice of the fat. Does the number of feeding birds increase? Put a piece of fat into a paper bag and place it outside the window. How much time will it take for the birds to reach the food? Prepare a story about your observations of bird's behaviour.

2.50 Reproduction and Development of Birds

REPRODUCTIVE ORGANS. Birds are dioecious. The male has paired testes, and the female has one ovary. Outlet ducts lead from the reproductive organs into a cloaca (two sperm ducts, or an oviduct).

FERTILIZATION OF OVUM AND EGG FORMATION. During reproduction the ovary resembles a small bunch of grapes. Each "grape" of this bunch is a thin-walled follicle with an ovum (egg cell) inside it. When maturing, the latter increases in size and accumulates nutrients that transform into the yolk of the future egg. The envelope of the follicle ruptures and the ovum emerges from the ovary into the oviduct, where it is fertilized. Fertilization is internal in birds like in reptiles.

Then the embryo starts to develop and a thick vitelline membrane of albumen grows around the yolk. The latter membrane is produced by special glands in the walls of the oviduct. The albumen is enclosed in a soft inner *shell membrane* and a firm *limy outer shell*, thereby forming an egg. The shell membrane and the firm egg shell are produced by the secretions in the lower parts of the oviduct. The eggs of many birds are coloured in the oviduct with various pigments before being laid. The eggs of birds which nest in the hollow of tree trunks and other closed shelters, are usually pigmented only one colour: white or pale blue. Birds who build open nests lay eggs with a characteristic pattern of cryptic colouration.

The entire process from the time the ovum emerges from the ovary to laying an egg takes about 24 hours. A bird lays only one egg at a time.

STRUCTURE OF A BIRD'S EGG. The inside of a laid egg is filled with a yolk, having a *blastodisc* (a disk of cytoplasm) on its upper surface (this is the embryo of a bird at a very early stage of development). The yolk is enclosed in a very thin vitelline membrane and is suspended within the fluid albumen by two spiral dense albumenous bands, *chalazae*.

The yolk, which is anchored on the chalazae, is mobile and is so arranged that the blactodisc, irrespective of the position of the egg in the nest, is always at the top, closer to the warm body of the hatching bird.

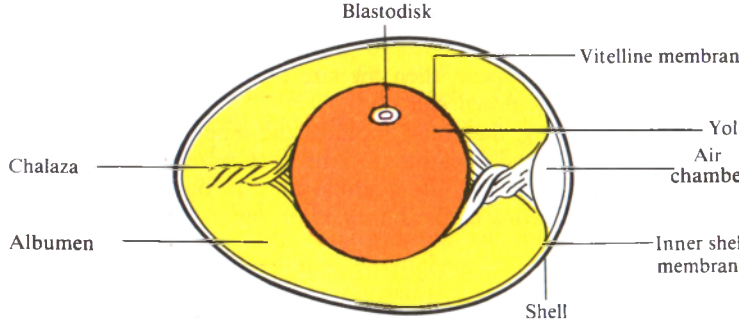


Fig. 118. Structure of a bird's egg. Diagram

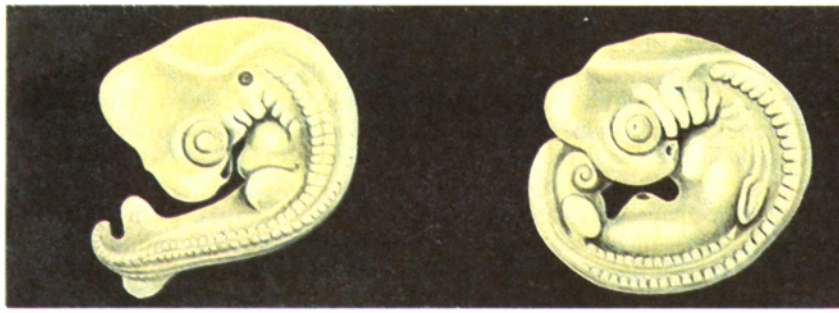


Fig. 119. Embryos of a reptile and a bird

The inner shell membrane, enclosing the albumen laminates at the large end of the egg and forms a small air space.

The limy shell is permeated with tiny pores so that air penetrates into the egg and gaseous products of embryonal activity are expelled. The shell is enclosed on the outside in a very thin envelope, protecting the egg from the penetration of microbes. Therefore, bird eggs intended for storage, should be kept unwashed so as not to damage this envelope.

The embryo only begins to develop in the oviduct. Rapid growth and major changes occur when the egg is laid and the parents begin to hatch it, i.e. to warm it.

The embryo does not resemble an adult bird at the early stages of development: its head is very big, the beak is like a tiny knob, the mouth runs along the anterior edge of the head. The neck carries several pairs of well pronounced gill slits.

The presence of gill slits in the embryos of birds, reptiles, and mammals (as we shall study later) proves that the ancestors of terrestrial vertebrates were fish-like animals.

During the initial stages of development of a bird's embryo the tail vertebrae are long, the forelimbs resemble the hind ones. All these features are evident in the embryos of lizards, crocodiles, and turtles. This resemblance points to the kinship between birds and reptiles. In the course of subsequent development, the embryo grows more like a bird from day to day: rudiments of down appear, then the size of the beak increases, and the growth of the tail slows down sharply.

Shortly before hatching, the chick ruptures the inner membrane of the air chamber with its beak and breathes for the first time with its lungs. The cheeps of the chick in the egg are audible at this time. Then it ruptures a hole in the shell by means of the horny knob on its beak (egg tooth) and emerges.

? 1. Where is the embryo in an egg?
2. What is the significance of the yellow yolk?
△ 3. Why doesn't a chick suffocate inside the egg shell?

4. What specific features in a developing chicken embryo point to the origin of terrestrial vertebrates from piscine ancestors?
5. What specific features in the embryos of birds and reptiles point to kinship between these two phyla of vertebrates?

■

1. Carefully pour the contents of a fresh chicken egg into a saucer. Find the blastodisc on the yellow yolk, and the chalazae in the white yolk.
2. Puncture the yellow yolk by means of a preparation needle. Why does it now spread about?
3. Take an egg shell and examine its external surface under a magnifying glass. What do you see? Find the inner shell membrane.

2.51 Nesting Season

PRENESTING PERIOD. The avian world becomes animated in early spring after a quiet winter. The warbling of great titmice and nuthatches, who wintered in our forests, is increasingly perceptible on cloudless days, and the drumming woodpeckers are busy at work. The snow melts away gradually, grass shoots its way out of the soil, the first insects begin to fly or crawl about. Birds return, having spent the winter in warmer regions. They nest usually in the same part of a forest or a meadow where they bred young birds in the past years. The male begins to sing here in spring, calling a female and informing males of his species that the area is occupied. The male sometimes fights with rivals, blocking their attempts to occupy his territory. The male and female feed here together and later build a nest.

PAIRING. NEST BUILDING. Many birds pair only for one season, for example, geese, and the majority of small species of songbirds. The males and females of ducks and pheasants stay together only up to the time when the eggs are incubated. Birds of prey, storks, herons, and some other birds live in pairs for many years, while wood grouse and black grouses never unite into permanent pairs.

The majority of birds lay eggs in a nest that is more often than not built by the female, but sometimes it is built by the male. Quite often they cooperate in building the nest: the male brings the material, and the female sets and secures it. Big birds of prey, rooks, pigeons build simple cup-like nests. The main material is twigs and boughs. Chaf finches and goldfinches build semispherical nests that are coated on the outside with moss and lichen. They are almost invisible from the ground because they melt into the pattern of the bark and lichen on the tree branches.

The tiny wren also builds a ball-like structure of moss, stalks, and twigs, fastened together with hair. Many birds of the woods, for example, woodpeckers, nuthatches, titmice, flycatchers, lay eggs at the bottom of a hollow in the trunk of a tree, or make a nest there.

Sand martins nest in burrows in precipices at the edge of a water body, or near it. The male and female dig out a burrow with their claws. They make

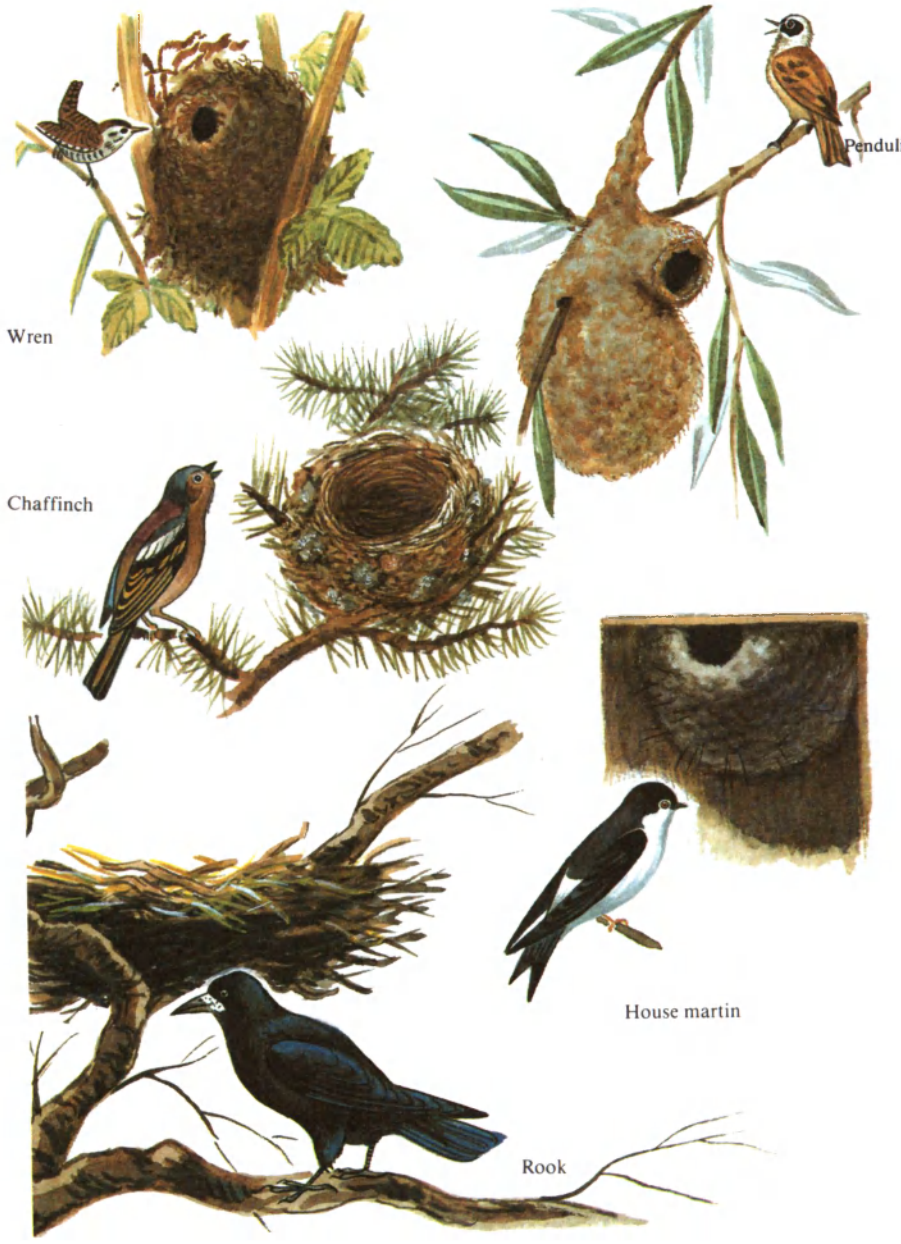


Fig. 120. Nests of various birds

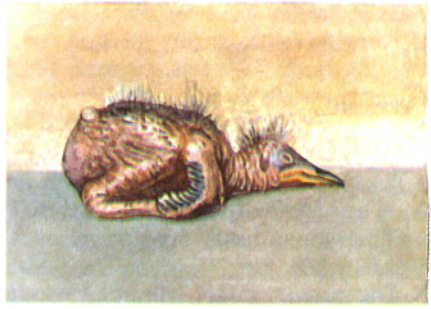


Fig. 121. Starling nestling

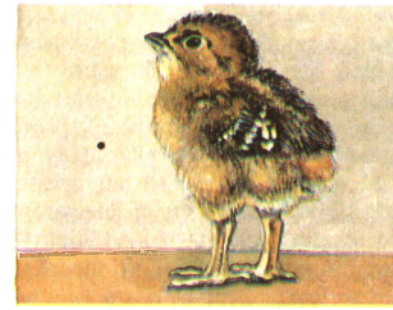


Fig. 122. Black grouse nestling

a widening, a nest chamber, about one meter away from the entrance to the burrow. The nest is woven of grass stems and lined with feathers.

House martins fix their structures, that are made of lumps of moist clay soil, to the wall of a house under the cornice, reinforcing the material with saliva. Thus, the nest has a readymade roof and a small entrance under it.

Many birds (for example, ducks, cranes, pheasants) make their nests right on the ground. Some birds, for example, razorbills and murres, lay one egg without any bedding right on an open rock over the sea.

The well-known cuckoo manages without a nest. The female lays 10–12 eggs, one egg at a time and in different nests of other birds for incubation. The young cuckoo rids the nest of the hosts' nestlings and the lonely parents feed the stranger. The feathered cuckoo nestling is usually much bigger than its adult hosts.

The number of eggs in the clutch is quite variable. Big birds of prey (for example, eagles), emperor penguins, and some other birds hatch only one egg. A titmouse may deposit up to 15, and partridges up to 20 eggs.

Frequently both parents are busy hatching the eggs, replacing one another in the nest, while in the case of naceous birds and ducks only the female does it.

Small birds hatch their eggs for about 14 days, larger birds somewhat longer. Thus, a chicken hatches her eggs for 21 days, while a swan and large predatory birds take about 1.5 months. Brooding birds turn their eggs around in the nest from time to time. This provides for more even warming, which aids the fast development of the embryo.

Some birds don't incubate their eggs at all. For example, brush turkeys in Australia and on the islands of the Malay Archipelago bury their clutch in the soil, where the embryo develops under the effect of the heat from the surrounding earth.

The nesting season is a crucial time in the life of birds and they should not be disturbed at this time. Frightened birds may abandon their nests and then the nestlings will perish.

TYPES OF NESTLINGS. Nestlings of black grouses, hazel grouses, ducks, geese, swans, and poultry are hatched covered with down and with open eyes. Several hours after hatching or on the next day they can leave the nest and even

run behind their mother. These young birds are called *precocial* ones. Despite their independence, the young birds need some warming during the first days of their life and hide frequently beneath the mother's wings, because their body temperature does not stabilize immediately.

The offspring of birds of prey, ravens, rooks, pigeons, woodpeckers, parrots, all songbirds, and many other nestlings hatch quite helpless, with fused eyelids and closed ear openings. Their body is naked, or is covered with individual patches of fine rare down. They are incapable of locomotion, and remain in the nests for a long time. These young birds are *altricial* ones. Altricial young are fed by the parents even when they leave the nest and start to flutter from one tree to another. The parents stop feeding the young when the latter start to fly independently.

CARE OF YOUNG. Care of the young is quite complex, especially care of young birds who remain in the nest for a long time. The parents warm and feed them, making about 400 rounds a day with food; they protect them against overheating by sun beams: if natural shade is not available, a parent stands with open wings over its offspring in the hot time of the day. The parents regularly carry away the dung of the young in order to keep the nest clean.

The adult birds protect their offspring zealously when an enemy appears. If a bird of prey walks or flies near the brood, the parents raise an alarming clamour, the neighbouring nesting pairs join in, and together they all go after the intruder so that he is forced to retreat. Sometimes the mother tries to draw the attention of a man or a dog away from her nest, pretending to be wounded. When the enemy tries to grab her, she flies further and further away, and then disappears.

The behaviour of birds, associated with care of the young, is instinctive, just as the behaviour of bees, burying beetles, sticklebacks, and other animals. When the adult birds remove the dung from the nest, they don't know that it is necessary for the correct development of the young bird's plumage and for the preservation of its health. Birds also do not teach their young to pretend to be wounded.

? △

1. What is the meaning of the complex behaviour of birds during the prenesting period?
2. What is the difference between precocial and altricial nestlings? Determine in Figures 121 and 122 which nestling is a precocial one, and which is an altricial one.
3. How do birds care for their young? (Use the material of your summer observations in your answer.)

2.52 Migration

Settled birds live in the same habitat the year round. Some of them gather small food reserves at the end of the summer for winter. Jays hide nuts and acorns in pits and in moss on the ground surface, or in hollows in the trunks of trees. Titmice and nuthatches store seeds and

insects, sticking them into cracks in the bark of trees and in the lichen on tree branches. They feed on these reserves in winter and in spring when food is scarce.

MIGRANTS. Other birds at this time join into small flocks and migrate gradually to the south. For example, rooks, and bullfinches search for regions with little snow and rich in berries and other food. These birds don't have permanent wintering grounds.

In autumn migratory birds fly from cold and temperate regions to warmer countries where they spend the winter. They unite in flocks numbering hundreds and thousands of individuals; some fly in the daytime, while others fly at night. The birds feed en route, rest, and fly further to their habitual wintering grounds.

Some migratory birds abandon their nests only in late autumn, when it is impossible to find any food. For example, many ducks and swans migrate when the water bodies, which are the main source of food for these species, start to freeze.

Other migratory birds, for example, nightingales, orioles, swifts leave for their wintering grounds quite early, at the end of summer, though the weather in their habitats is still warm and there is more than enough food.

During migration, the birds keep to permanent routes that they follow every year to the wintering grounds, and in spring they return to breed.

METHODS OF STUDYING MIGRATIONS. In order to learn where the

Fig. 123. Migration routes of the white stork

birds spend the winter, a light ring with a stamped number and the country where it was ringed is put on one of the bird's feet and then it is set free. The species of the ringed birds is recorded in a register, also the ring number, date and place of ringing. If a migrating ringed bird is caught or killed by hunters, the ring is removed and sent to the city stated on it; information is also sent about where and when the bird was caught or killed.

Ringing has made it possible to learn that common swallows and house martins migrate from the European part of the USSR to South Africa, and even to India. European white storks migrate for the winter to tropical and South Africa. Our nightingales winter in South Nigeria and in the basin of the Zambezi (South-East Africa).

REASONS FOR BIRD MIGRATIONS. Experiments have established that birds who migrate early but are kept in cages in closed rooms, exhibit great anxiety in autumn. Investigations of their movements indicate that they seek to fly in the direction of their permanent wintering grounds. They calm down a few weeks later and everything returns to normal.

By comparing the dates of anxiety of caged birds with the behaviour of free individuals of the same species, it has been determined that the dates correspond to the time of autumnal migration of free birds.

Scientists think that the migration of birds is associated with long established seasonal changes in living conditions. Birds, whose habitat is in tropical regions, also migrate. For centuries many of them migrate from regions with annual droughts and heavy showers to northern and temperate areas where they were bread, enabling them to exploit the warmest season of the year for nesting, which is most favourable for feeding and bringing up the young. As a rule, the striving of birds in spring to reach their ancestral breeding grounds is associated with the instinct of reproduction, and autumnal migration is conditioned by a decrease in the amount of habitual food, a shorter day, which is a signal for migrating from areas where there will eventually be a food shortage. Thus, migration is an instinctive action of birds and it developed several million years ago under the effect of seasonal changes.

This change of the habitat twice a year promotes the revival of many bird species because they have abundant food supplies all year round in this case. Repeating from one generation to another over the course of many centuries, migration turned into a complex, instinctive, inherited form of behaviour, which has not yet been fully explored.

? △

1. What living conditions have induced the migration of birds?
2. Why are birds ringed?
3. The scale of the map (Figure 123) is 1 cm: 1650 km. What distance (approximately) will white storks cover when migrating to their wintering grounds?
4. What birds known to you winter in your region, and what birds migrate for the winter?

2.53 Origin of Birds

SIMILARITIES BETWEEN BIRDS AND REPTILES. It is easy to find a certain resemblance between the two classes when examining the specific features in the structure of birds and reptiles. The skin of reptiles and birds has hardly any glands. It is covered with horny scales on reptiles, and the same scales are developed on birds on featherless parts of the skin, for example, on the tarsometatarsuses. The feathers of birds are also horny formations, resembling in origin the scales of reptiles. The structure of the eggs, rich in yolk, is similar in the representatives of both classes. The embryos of birds and reptiles are similar in their appearance. Similarity in the organization of birds and reptiles indicates a certain relationship between these classes of chordates.

The differences between birds and reptiles point to the higher evolution of birds. It is confirmed by the enlarged brain (in particular, the larger sizes of the hemispheres and cerebellum in birds), the perfection of the respiratory and circulatory systems, including double respiration and separation of the arterial and venous blood, the constant temperature of the body. All these improvements in the organization of birds are lacking in reptiles.

ANCIENT BIRDS. Fossil bones of a skeleton of an unknown creature and imprints of feathers near the skeleton have been discovered in the strata of the earth's crust. Scientists restored the appearance of the animal. It was the size of magpie and features common to a reptile and a bird. The shape of the skull with teeth in both jaws and the very long tail with 20 vertebrae resembled a reptile. However, the body of this creature, except the head, was

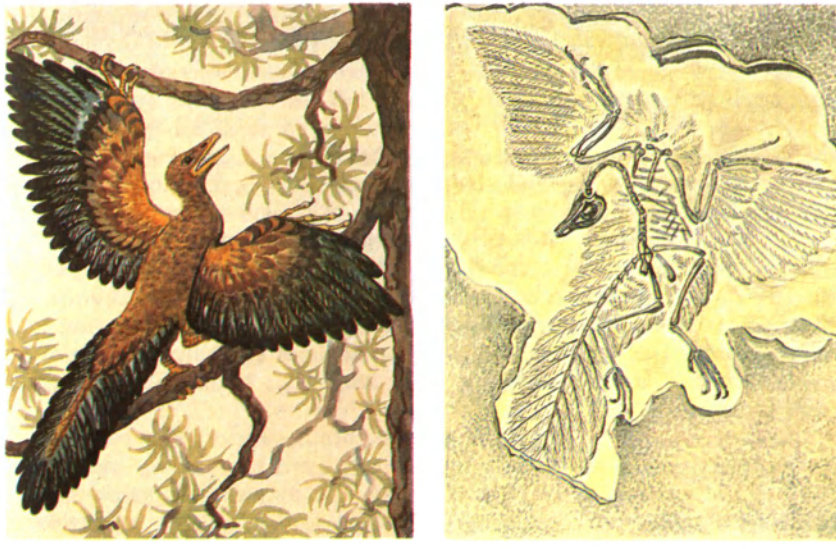


Fig. 124. Archaeopteryx: conjectural view, skeleton bones and feather imprints

covered with feathers, and the forelimbs had all the main features of bird's wings with flight feathers. Only the digits of the wings were longer than in modern birds and they had claws. The feet had four toes each: the first toe pointing backward, and the rest pointing forward, enabling the animal to grasp a branch firmly with its toes. The rectrices were attached in pairs to each vertebra of the long tail, unlike modern birds who have a fan-like arrangement of these feathers on the tail bone. The animal was called *Archaeopteryx*, meaning *ancient bird.* It lived about 150 million years ago. Ancient birds lived in trees, springing and crawling in the branches, clinging with the long toes of the claws of the forelimbs. They could fly: spreading the wings, they could glide down an inclined plane, or fly over small distances by flapping their wings.

The ancestors of the archaeopteryx are also known by fossils. Scientists assigned them to the class of reptiles. These animals ran on their hindlimbs; they used the hind and short forelimbs to move about in the trees. Their body was covered with small scales, whose structure resembled the feathers of birds. Evidently, they developed feathered wings and started to fly when adapting to life in the woods.

The specific features in the structure of the most ancient bird known to us, the archaeopteryx, are evidence that the first representatives of this class appeared and learned to fly when they lived in the woods on tree branches. Only some birds at a later time adapted to life in the steppe and deserts, on the banks of water bodies, and in other places.

△ 1. Write the features of reptiles in the structure of the archaeopteryx down in your notebook on the left side, and features of modern birds on the right side.

? 2. How can the similar features in the structure of birds and reptiles be explained?

2.54 Birds of Parks and Orchards, Meadows and Fields

We know birds of cultivated areas the best because we see them more often. Many of them live in forests too. These birds are most beneficial because they exterminate harmful insects in orchards, meadows, gardens, and fields. Many of them are songbirds, and, therefore, they should be cherished. All the birds of cultivated areas should be preserved and cared for by creating convenient places for nesting to attract them.

ORDER: PASSERIFORMES. Representatives of the order of passeriformes make up the major mass of birds of cultivated areas, including more than half of all the species in the class of birds. The majority of passerines are insectivorous birds, and their offspring always feed on insects, though the parents may be seed-eating birds. These birds are usually small or of average size.

Fig. 125. Swallow

Fig. 126. Titmouse

The great titmouse (!) is a beautiful, lively bird the size of a sparrow. It is distinguished easily by the greenish coloration of the back, yellow breast with a black band, and a black hat on its head. It is one of the first, who at the end of February or the beginning of March, sings a short clear song, as if informing everyone of the approach of spring and warmth.

The great titmouse is very fertile. It nests very early and deposits up to 12 eggs. The nestlings emerge two weeks later and the clutch leaves the nest after another three weeks. The adult birds soon start to lay eggs again, sometimes in the same nest.

Great titmice occur in mixed forests, there are many in parks, orchards, near human dwellings. They unite into small flocks in autumn and in winter. Fluttering from one branch to another, the titmice carefully examine cracks in the bark in search of hiding insects.

SWALLOWS. The house martin, the swallow, and the sand martin (!) spend a great part of the day in flight, catching insects (small flies, mosquitoes, gnats) in the air. They pursue their prey right above the ground surface and high in the sky. The flight of swallows is swift, light and adroit, owing to their long sharp-tipped wings. Swallows hunt tirelessly the whole day in the air. They even drink while in flight, flying low over water and catching it with an open bill. The wide mouth and small flattened bill contribute to success in catching prey. Their feet are small, they walk clumsily and rarely sit on the ground.

SKYLARK (!). The silvery clear warbling of skylarks resounds high in the sky in early spring over fields and steppes. Skylarks return from their wintering when thawed patches appear in the fields. These birds live on

meadows, in steppes, they settle readily on croplands, where they find abundant supplies of food and shelters for a nest that they build right on the ground. A skylark can be easily seen in the sky, where it flies in circles and sings its modulating song. It is difficult to see it on the ground as the modest, grayish-brown plumage with dark spots makes a skylark almost invisible in the grass and field vegetation. A skylark feeds only on the ground and never catches prey in flight. A skylark runs swiftly among plants, looking for prey and grabbing it from the ground or blades. Adult birds and nestlings feed mainly on insects.

? 1. What accessories of swallows assist the latter in catching insects in flight?
△ 2. What is the benefit of passerines?

2.55 Forest Birds

Many different birds live in the forest. We have studied some species that settle also in gardens and parks. Furthermore, there are birds in the forest that you will never see in a park, or occur there very seldom.

ORDER: PICIFORMES. The spotted woodpecker (!) is slightly bigger than a starling. The plumage of a woodpecker is black with white bands, the part beneath the tail is bright-red, and a male also has a red transversal band on

Fig. 127. Woodpecker

Fig. 128. Wood grouse

the back of the head. The head is large with a firm, sharpened, chisel-like bill. The neck is thin, and the feet are short with sharp claws bent backward.

When a woodpecker sits on a horizontal branch of a tree, or leaps on the ground, two toes on each foot point forward and two backward. The position of the external hind toe changes entirely when the bird climbs a vertical tree trunk: the woodpecker turns it sideways at a right angle to the fore toes. In addition, the bird's body is supported also by the tail: the firm, elastic tail feathers rest with force against the tree bark. This position of the toes and tail provides the woodpecker with a very strong support on the tree trunk when the bird is pecking with its bill. A woodpecker feeds on adult beetles, who live in the open, and on their larvae, that live under the bark and in the wood. The bird pecks the trunk of a tree which has been damaged by insects, and catches the larva with its tongue. In autumn and in summer it also eats seeds of coniferous trees, pecking them out of the cones. To reach the seeds in the cone, the bird sticks the cone into a crack in the bark, or into a split in a broken branch, and pecks it.

ORDER: GALLIFORMES. GALLIFORMES OF FORESTS. Hazel grouses, black grouses, wood grouses live in our northern coniferous and mixed forests. Their bill is relatively big, the apex of the culmen is sharpened and angled slightly downward, the nostrils are concealed under feathers. Bright-red eyebrows grow in spring over the eyes of males.

The wings of these birds are short, rounded, and they fly with difficulty, taking off from the ground with noise. Their feet have four toes with big claws, and are thickly feathered. In winter the toes have horny edgings that help them walk in loose snow. They don't migrate for the winter.

Hazel grouses, black grouses, and wood grouses are ground nesters. They search for food on the ground also. These birds feed on all the berries that grow in the forest (bilberries, cowberries, juniper berries, dog rose), the green parts of herbaceous plants, and catch insects. They spend much time in the trees where they feed on the buds and catkins of berch and alder trees. The cock of the wood and sometimes the black grouse feed on pine needles. They pass the night usually high up in thick branches, but in winter they burrow into loose snow, where they spend not only the whole night but even a part of the day if the frost is biting.

All the birds liven up in spring and begin to sing. Excitation is displayed by black grouses and wood grouses in very peculiar games, or courtship rituals, that are characteristic only of these birds.

Polyphonic mumbling is audible in the forest early in the morning, meaning that male black grouses have settled on the crowns of the still naked birches and have started their peculiar "singing". After some time they fly down to a clearing among the trees, or to the edge of the forest with bushes, where they begin to walk and run on the ground, opening their wings and dragging them behind. The black grouses run into one another, hissing and fighting with their bills.

A male wood grouse performs his courtship rituals on a branch of a pine-tree, frequently on a mossy bog, and sometimes on the ground. Its wings are suspended, the head is raised, and the tail is spread. The song of

Fig. 129. Red jungle fowl

Fig. 130. Hazel hen

a wood grouse is muffled. At first one hears some trilling, and then chirring. When it sings, the wood grouse pays no attention to the activities around him, it seems he sees and hears nothing, and it is possible to approach him quite closely.

WILD FOWL. Wild jungle fowl, ancestors of domestic chickens, occur in tropical forests, at the foot of the Himalayas, in South India, Burma, and all over South-East Asia. Breeds of domestic birds are discussed in the section "Poultry Production" (p. 152).

? 1. How does a woodpecker find food?
2. What is the benefit of woodpeckers?
△ 3. What accessories have developed on the covering of the feet of galliformes in northern forests owing to cold and snowy winterings?

2.56 Birds of Prey

ORDER: FALCONIFORMES. Diurnal birds of prey live in steppes, deserts and forests, plains, and in the mountains. They prey upon various small animals, birds, rarely on fish, and still less on insects. They don't eat plant food at all.

Some species of predatory birds, for example, neophrons, griffons, vultures, bearded vultures, are carrion feeders. Others prefer living prey, and their number is greater, including falcons, eagles, buzzards, hawks, harriers, etc. Most often, birds of prey feed on harmful rodents, and in this way are beneficial to man.

Vultures are characterized by a heavy body, slow movements on the ground. They walk clumsily but can make swift steps to drive a rival away from some carrion. They have a powerful bill, which is bent at the tip. A vulture is unable to grab prey with its feet, therefore, its claws are blunt. The broad wings are adapted for lengthy hovering flight. The wing spread reaches 2.5 m.

Fig. 131. Vulture

Fig. 132. Owl

Vultures hover for hours over treeless mountainous regions and flat country, looking around from a tremendous altitude for prey. The predator flies down at a high speed when it sees a motionless body on the ground.

Neophrons, griffons and vultures are recognized easily by the slightly feathered front part of the head and neck.

The habits of falcons are quite different. Seeing a flying bird (a duck, a partridge), or a running animal (a souslik), a falcon attacks the prey from above, stunning it with an impact of its talons on the rear toes of both feet. It grabs the prey with its talons, bites through the vertebral column at the head using the sharp edges of its bill. It then carries the prey to some secluded spot and eats it.

ORDER: STRIGIFORMES. At nightfall, when the voices of diurnal birds abate, nocturnal birds of prey start to hunt, for example, owls, eagle owls, little owls, barn owls. These birds have strong hooked beaks and sharp talons.

Their big eyes with widely opening pupils can see tiny objects in very dim night light, and their keen sense of hearing perceives the slightest rustles. Unlike diurnal predatory birds, owls have soft, loose feathers that enable them to be silent fliers.

At night-time, when it is quiet, the silent flight helps the owls to hear well and to appear suddenly over the prey. Owls are rarely seen in the daytime because they hide in secluded corners.

■ Think of some questions on each part of the section.

2.57 Birds of Bogs and Banks of Water Bodies

WATERFOWL. The life of many birds is closely associated with water bodies, wherein they find food. Waterfowl, as the name indicates, can swim, and many of them dive. Owing to their adaptation to swimming and diving, waterfowl have webs between the toes on the feet, and the feet proper are set far back on the body.

The majority of waterfowl have a slow and clumsy gait on the ground.

The plumage of waterfowl is preserved against getting wet mainly by the structure of its feather covering. The thick intertwining of the feather and down barbs forms a thick layer with a water-repellent external surface. Furthermore, innumerable air bubbles in the very thin cavities of the feather layers contribute to waterproofness. Lubrication of the feathers by secretions from the uropygial gland is also important in protection against water: it preserves the natural structure, form, and elasticity of the feathers, making a waterproof layer.

Birds of many orders belong to waterfowl. Let's study the representatives of two orders.

ORDER: ANSERIFORMES. A mallard lives in forested flood-lands of slowly flowing rivers, on the banks of lakes that are almost grown over with reeds, on grass bogs with small water bodies. It swims well, paddling with its feet, and dives only in cases of danger. It flies very well and waddles when it walks.

A mallard's body is slightly flattened, the neck is rather elongated, the feet are short; three toes are webbed, and the first is free.

When feeding on a shallow place, a mallard, like the majority of other freshwater ducks, usually dips with its head underwater, while its tail remains above the water surface. The duck stretches its neck and explores the soft bottom of the water body with its bill, while its feet are working boisterously to keep the body in a vertical position. A mallard's bill is broad and has a blunt tip. A row of narrow, transversal horny plates are arranged at the edges of both jaws. When feeding, the mallard opens its bill slightly and sucks in water or liquid ooze, and then filters it through the horny plates,

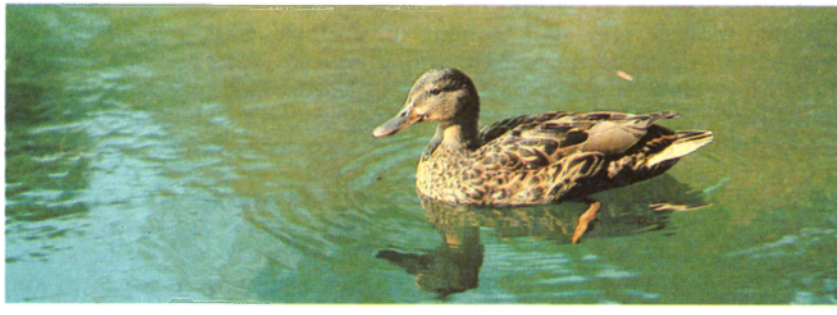


Fig. 133. Mallard

swallowing the remaining food. It eats the green parts of plants and seeds, also tiny crustacea, beetles, dragonfly larvae, and mollusks.

In spring the mallards unite into individual pairs. The male (a drake) is more brightly coloured than the female, the plumage on his head is bright-green, and on the female's is dark-brown.

Mallards nest in our country everywhere, except the far north of Siberia. In autumn, when the water bodies freeze and it is difficult to find food, they migrate to areas with nonfreezing water bodies.

Mallards, who nest in the European part of the USSR, winter along the coast of West and South Europe, and migrate from Siberia to the South of the Caspian Sea, to India and China.

ORDER SPHENISCIFORMES. Penguins (!) inhabit the coasts of continents and islands of the southern hemisphere. The emperor penguin occurs only in Antarctica. Penguins go ashore to breed, and stay in the high seas the rest of the time. These birds are excellent swimmers and they dive in search of fish, mollusks, small crustacea, but they cannot fly at all.

The penguin's wings are small and are shaped like narrow flat flippers. The muscles of the wings and the entire breastbone (sternum), to which they are attached, are developed like in good fliers.

The feet are short and webbed. The legs stretch backward when swimming and serve as a rudder. Penguins walk on ice and snow, holding their body upright and resting on the feet and tail.

Emperor penguins come out on the ice to breed. They don't build nests and hold the single egg on the webs of the feet, hiding it under a big fold of skin on the belly. They incubate the egg, standing upright. It is very noisy in

Fig. 134. Penguins in the Antarctica

the colonies of penguins. The hatching chicks are covered with thick down and are very fat, but they are helpless and develop slowly. The parents feed the chick with regurgitations of food into the mouth, or the chick sticks its bill into the pharynx of the parents and drags out whatever it can. During blizzards and snowstorms, the grown chicks huddle into a tight crowd and press to one another for warmth.

Wading birds also keep near water, but they can neither dive nor swim. They walk in shallow waters on long legs and catch various aquatic animals with their long thin bill. The neck of wading birds is also quite long.

ORDER: CICONIIFORMES. The white stork (!) is a large bird with big black wings and long red feet. Storks occur in open areas with sparse groups of trees, also in places with vast lowland meadows, bogs, water bodies. A stork can go far into the water, owing to its long legs. The long toes with a small web between their bases enable a stork to walk with confidence in marshy areas.

Storks are migratory birds and winter far away from their nesting grounds in Central and South Africa, and in some regions in South Asia.

? 1. How does a mallard feed?
2. Why don't the feathers of a duck ever get wet, though it stays for a long time in water?

△ 3. Talk about the migration routes of the white stork as shown in the map in Figure 123.

2.58 Birds of Steppes and Deserts

The living conditions in open areas are distinguished by certain specific features. It is difficult to find a shelter, therefore, many birds, inhabiting steppes and deserts, have long feet and a long neck, which enables them to see far and wide across the area and notice opportunely the approach of predators. Birds of steppes and deserts find food on the ground and in the vegetation. They must walk much in search of food, and therefore, their feet are usually well-developed. Some species escape from predators by running away instead of flying off.

ORDER: GRUIFORMES. Triangles of cranes fly with loud calls high in the sky in April. They are returning from Africa and South Asia to their nesting grounds. The majority of cranes occur in marshy areas, but the demoiselle crane (!) nests in the European and Asian steppe zone of our country. The cranes start their nuptial games immediately upon return. They assemble in a big circle and several pairs "dance" in the centre to loud blaring sounds. After some time the "dancers" join the circle of "spectators", letting other birds have the dancing floor.

Demoiselle cranes are ground nesters in the steppe, or on plowland. The nest is a shallow pit with stems of grass. The clutch contains two eggs. These

Fig. 135. Ostrich

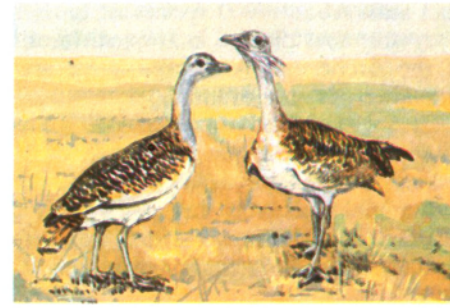


Fig. 136. Bustards

cranes feed mainly on plant food, and less on insects. Demoiselle cranes are rare and need to be protected.

ORDER: STRUTHIONIFORMES. Ostriches are the most remarkable dwellers of steppes and deserts. They are very large flightless birds with a heavy body on long powerful legs. The feet of the African ostrich are two-toed with big claws.

African ostriches dwell in groups, sometimes in herds of large mammals. Its large stature, keen vision, and cautious nature enable an ostrich to be the first to see danger and to frighten away the whole herd. It escapes its enemies (a predator or a hunter) by running away. A running ostrich makes 4 m long strides and reaches a speed up to 70 km per hour. When it meets with an enemy, an ostrich fights with its feet, inflicting serious wounds.

ORDER: GRUIFORMERS. A bustard (!) is one of the largest and rarest birds in our country. Its mass reaches 16 kg. Bustards make their habitat in steppes. Owing to their keen vision, they see danger from afar and either fly off, or run away on their powerful legs. A bustard hides sometimes in sunburnt grass and becomes entirely invisible owing to the cryptic colouration of its plumage. Bustards are onmivorous birds: they eat leaves, seeds, shoots of various plants, also beetles, locusts, lizards, small rodents. The chicks feed mainly on insects. In case of danger, the female pretends to be wounded and draws the attention of the enemy away from the chicks, running aside with suspending wings. The chicks press down to the ground in order to hide themselves.

2.59 The Role of Birds in Nature and Their Practical Significance for Man

SIGNIFICANCE OF BIRDS IN NATURE. Birds inhabit all the continents and the majority of islands around world. They are distributed throughout the world where there are plants and animals that they can feed on: in forests and gardens, in meadows and bogs, in steppes, the tundra and deserts. Some birds spend a greater part of their life in the

high seas. About 9000 species of birds are found in the world fauna today. They are most diverse in tropical forests, while under the severe conditions of the Arctic and Antarctica there are fewer species, but the number of individuals is tremendous.

The role of birds in nature is quite significant owing to their diverse activities and very great number. It has been calculated that about 100 billion birds inhabit the world. They consume a large amount of vegetative and animal food every day, rendering a great effect on the living nature. The significance of birds is the greatest in regulating the number of insects and small rodents. Sometimes birds serve as food for other animals.

Birds do important work in spreading seeds. Pecking the juicy fruit of mountain ash, elder, cowberries, bird cherries, blueberries, and of many other plants, they fly from one place to another and excrete undamaged seeds together with their faeces. As a result of this activity the heavy acorn, the fruit of oak trees, occurs far away from the tree where it grew. Jays and other birds, feeding on acorn, carry them over long distances and frequently lose them during flight. The flowers of tropical plants are pollinated by birds, for example, humming-birds and sun-birds, who feed on the nectar of flowers like many insects.

The significance of birds for man depends mainly on the role they perform in nature. All insectivorous birds are considered to be beneficial, because they exterminate insects, primarily various mass pests of cultivated crops and valuable wild plants. Therefore, it is important to protect birds and attract them to fields, gardens, and orchards.

Fig. 137. Starlings near bird-house

Fig. 138. Bird-feeder for wintering birds

Birds of prey are undoubtedly very useful for man, because they exterminate a great number of small rodents, pests of field crops, and carriers of many infectious diseases (plague, jaundice, etc.).

Many wild birds are hunted for commercial reasons and for sport, the majority being members of the order Galliformes (partridges, hazel grouses, black grouses, pheasants), and ducks in the group of waterfowl.

An eider, a large marine duck, nests along the coasts of Arctic seas. It lines its nest with a thick layer of down. Eider-down is very soft, elastic, and is characterized by poor heat conductivity.

Bird droppings contain a large amount of nitrogenous and phosphorous salts and are an excellent fertilizer. The amount of excrement (guano) accumulating at the nesting grounds of a large number of birds is so great, that it is exploited by industrial methods.

Bird feathers are very important in the history of culture, because they were used for writing from the time of the Roman Empire up to the middle of the last century.

PRESERVATION OF BIRDS. Birds are the primary and most reliable helpers of man in exterminating harmful insects and their larvae. If we preserve insectivorous birds, we shall always have a large army of tireless workers, who will protect forests and gardens against harmful insects. To preserve our winged friends, it is necessary first of all to protect them, and not to touch their nests and eggs.

Laws on environmental protection that have been adopted in our country, prohibit the killing of song birds and destruction of their nests. Birds of prey are also protected by the law.

Strict limits have been imposed for the hunting season to ensure reasonable hunting of commercial birds and to preserve them to the maximum. Hunting is prohibited everywhere during the breeding period.

Attracting birds closer to fields, orchards and gardens favourably effect the yield.

Birds frequently don't have a sufficient amount of convenient places for nesting. Therefore, it is necessary to hang up starling-houses and other artificial nests in the forest, in gardens and orchards in autumn and in winter, and to plant bushes that could serve as shelters for nests.

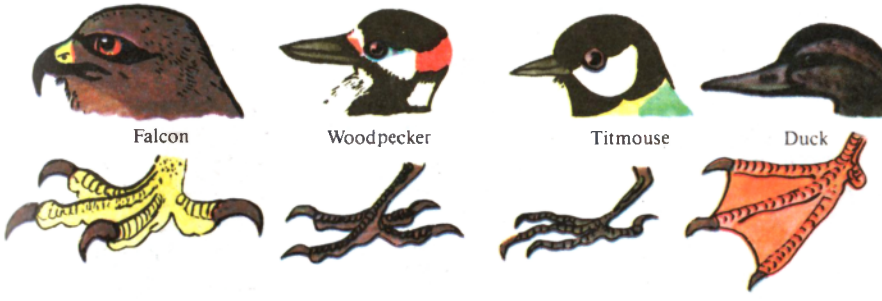


Fig. 139. Examine the bills (beaks) and feet of the birds in the figure. Tell us how these birds feed

Winter is a hard time, particularly for small birds. It is difficult to find food when the frost is biting, or during a snowstorm.

Birds can be fed not only in rural areas, but also in town if there are bushes or trees near the house. When searching for meagre food in winter, titmice, and sometimes bullfinches and waxwings appear in crowded streets of the city, examining every tree and bush, and very soon they find feeding racks that have been set on window-sills, or on the lawn.

Birds should be loved and preserved not only because they are beneficial for humans, but also because they are merry, beautiful, and their cheerful appearance and behaviour beautify and enliven gardens and forests. Furthermore, many birds are excellent singers and can put one in good spirits. Let's preserve and protect our feathered friends and helpers!

?
1. In what way are birds beneficial?
2. How can birds be attracted to fields, orchards, forests, and parks?

△
3. What have your friends and you personally done to preserve and attract birds?
4. Why is it necessary to preserve birds of prey?
5. How can you help birds during a cold and snowy winter?

2.60 Poultry Production

SIGNIFICANCE OF POULTRY PRODUCTION. Poultry farming is a profitable branch of animal husbandry, producing large amount of top-quality foods. Poultry meat is distinguished by a pleasant taste and is highly nutritious; chicken eggs are indispensable in the human diet for all ages. Eggs are also used in the food industry: they are included in the contents of the most varied food products, improving their taste, quality, and appearance. Eggs are used also in medicine for the preparation of various medications. Down feathers are used to make pillows and feather matrasses.

Diverse breeds of agricultural birds. Domestic birds such as chickens, geese, ducks, turkeys and others are divided into breeds which differ in terms

Fig. 140. Breeds of domestic chickens

of their qualities as used by man. *Breed* is an artificial variety of an animal as determined by man. (How man created breeds of domestic animals is discussed on p. 198.) The improvement of domestic breeds is a task taken up by collective farms, state farms, experienced pedigreed stock farms, and scientific institutes.

The people of ancient India domesticated wild jungle fowl about 4500 years ago and domestic poultry evolved from the latter. Today, the most numerous domestic bird is the chicken. Each breed is distinguished by specific features that are important for economic purposes.

Egg-laying breeds of chickens are reared mainly for egg production. They yield little meat (these chickens weigh 1.6-2.4 kg) but each hen lays 200-300 or more eggs per year. Chickens of the meat-and-egg breed (for example, the Plymouth Rock chicken which reaches a mass of 4 kg and more). Chickens of meat breeds are raised for meat chicks which weigh 1.6 kg and more at 2 months old.

Man domesticated the wild duck nearly 3000 years ago. Duck eggs are not very tasty, therefore mainly meat breeds of domestic duck are reared. Two months old ducks weigh 2.5 kg and more. It is most profitable to rear domestic ducks on carp ponds, because the dung of ducks is an excellent fertilizer for the water body, owing to which various invertebrates develop in abundance, serving as food for the fish.

Long before the Columbian Age, Mexican Indians domesticated birds of the order Galliformes, whom Europeans called turkeys. The latter were brought to Europe in 1530. Today they are reared to produce tasty and tender meat. Turkeys are the biggest domestic birds, their body mass reaches up to 16 kg. One turkey of the best meat breed can yield 40 to 60 head young turkeys. These will give 160 to 200 kg meat when they are three or four months old.

INDUSTRIAL POULTRY BREEDING. Large poultry complexes are designed for uninterrupted supply of the population with foods produced from domestic birds. Usually chickens are bred at these complexes. Some poultry houses specialize mainly in the production of chicken eggs, others in chicken meat. Each poultry house has a parent stock, i.e., an incubation shop (for breeding chicks), an industrial stock of laying hens, and at meat-producing houses there are shops for fattening the young. There are also shops for processing the eggs and meat birds, as well as by-products.

The chickens are kept in rooms specially equipped with automatic temperature control, maintenance of humidity, air composition, length of day and night. Artificial illumination prolongs the light part of the day in winter and stimulates the chickens to lay eggs. The birds are kept in special cages with a wire floor and walls. The food and water troughs are outside the cages. The birds feed by sticking their heads through an opening in the cage's wall, therefore the contents of the feeder are never mixed with any dirt.

The birds are fed highly nutritious mixed food of full value. This food is prepared from various fodder grains, milling waste, potatoes, root vegetables, and other products, vitamins that are necessary for the growth and

development of the organism, mineral salts, and some other substances contributing to better assimilation of the food.

The chicks are not hatched by the hen, but are incubated in special apparatus called *incubators*. As a rule, an incubator consists of two chambers. The first, bigger one, holds trays with eggs. The required temperature and humidity for the development of the embryos are maintained. Special devices turn over the eggs automatically every two hours because otherwise the membrane of the egg may dry up, killing the embryo. One or two days before the end of incubation, the trays with the eggs are transferred into the second, broad chamber of the incubator where all the conditions are maintained for the hatching chicks. A large incubator can hold up to 50,000 eggs simultaneously.

? △
1. What conditions should be created for birds at a poultry house?
2. What does incubation of eggs mean and how is it accomplished?
3. What breeds of domestic birds are most important for agriculture?

Class: Mammalia

2.61 External Structure of Mammals

DOMESTIC DOG. We shall begin to familiarize ourselves with the structure of mammals by studying the domestic dog. It was the first domestic animal; man domesticated it in ancient times. The domesticated dog helped the primitive man at hunting, guarded his dwelling. Today there are dogs of various breeds: guard dogs, hunting dogs, sled dogs, police dogs, pet dogs. These animals also help to guard the borders of our Motherland, and during the Great Patriotic War they searched the battlefields for wounded soldiers, helped in reconnaissance and communication services. Scientists study the vital activities of the organism using dogs. Dogs were launched into space before men.

The body of a dog, for example, a shepherd or an Eskimo dog, is slim and muscular. Its limbs are not located on the sides of the body, as in the case of reptiles, but under the body, therefore the body does not touch the ground. A dog walks on its tiptoes with strong claws. The supple neck contributes to great mobility of the head.

The mouth of the animal has mobile lips: upper and lower. A nose with a pair of external nasal openings, nostrils, is above the mouth. The eyes have well-developed eyelids. The nictitating membrane (third eyelid) is underdeveloped in a dog, like in all mammals. Among all the animals only mammals have an outer ear, a helix. The *outer ear* of a dog is big and mobile.

COVERINGS. The skin of mammals is firm and elastic, and the majority of animals have hair roots in it. The latter develop into a *hair covering*, which is

Fig. 141. Collie

characteristic of this class of vertebrates. The hair covering consists of coarse and long hair, *guard hair*, and shorter, softer *undercoat*. The coarse and strong guard hair protect the undercoat and skin from damage. The undercoat, holding much air, preserves the body heat very efficiently. Besides the guard hair and undercoat big hairs, tactile organs, also develop on the body integument of animals.

The hair of mammals, like the feathers of birds and the scales of reptiles, consists of a horny-like substance. A dog molts twice a year like many other mammals, i.e. a part of its hair falls out and is replaced by new hair. The hair root is inside a special hair follicle. The ducts of the adjacent sebaceous glands open into it. The gland secretions lubricate the skin and the hair which become elastic and don't get wet.

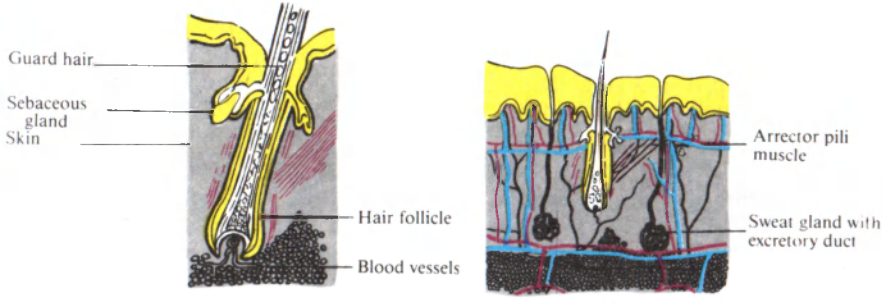


Fig. 142. Structure of skin and hair of mammals. Diagram

The majority of animals have sweat glands in the skin. Sweat, evaporating from the body surface, cools the animal. Excessive salt and urea are excreted from the body together with the sweat, hence, the sweat glands are additional excretory organs.

A dog has few sweat glands and cooling of the body is provided by rapid breathing or panting.

The toes of mammals end with horny claws, *nails*, or *hoofs*. Horny formations are developed sometimes on the head (horns on rhinoceroses, antelopes, horned cattle, etc.), or on the tail (for example, the horny scales on rat tails).

? △

1. What are the similarities and differences in the external structure of reptiles and mammals (use as examples a lizard and a dog)?
2. Talk about the structure of the glands in the skin and the role they perform. Use Figure 142 to illustrate your story.
3. What is the significance of the hair covering? Why don't whales and dolphins have it?

2.62 Skeleton, Musculature, and Body Organs of Mammals

A mammalian skeleton is very much like the skeleton of reptiles and consists of the same structures. The skull is larger, which is associated with the larger size of the brain. There are seven cervical vertebrae in most mammals. The long-necked giraffe and whales with no neck at all have the same number of vertebrae. The thoracic vertebrae (usually from 12 to 15) form a strong thoracic cage in conjunction with the ribs and breastbone (sternum). The massive vertebrae of the lumbar portion are jointed. The body can bend and straighten at these places. The number of lumbar vertebrae is different in various species (2-9), a dog has 6 vertebrae. The sacral part of the vertebral column (3-4 vertebrae) accretes with the pelvic bones. The number of vertebrae in the tail portion (from three to several dozen) depends on the length of the tail.

The pectoral girdle (or girdle of forelimbs) consists of two shoulder blades, with accreted coracoid bones, and two collar bones. The collar bones are underdeveloped in a dog. The pelvic girdle (girdle of hindlimbs), the pelvis, consists of three pairs of pelvic bones. The skeletons of limbs in mammals and reptiles are similar, but the structural elements are different in various species and depend on the living conditions of the animal.

The majority of mammals, including dogs, are characterized by well-developed muscles of the back, limbs, and their girdles. When running fast, a dog makes long leaps, bending and straightening its body, pushing off the ground alternately with its fore and hind legs. Strong muscles move the lower jaw. A dog holds its prey tightly with its jaws.

Like in other mammals, the floor of the mouth cavity is occupied by the

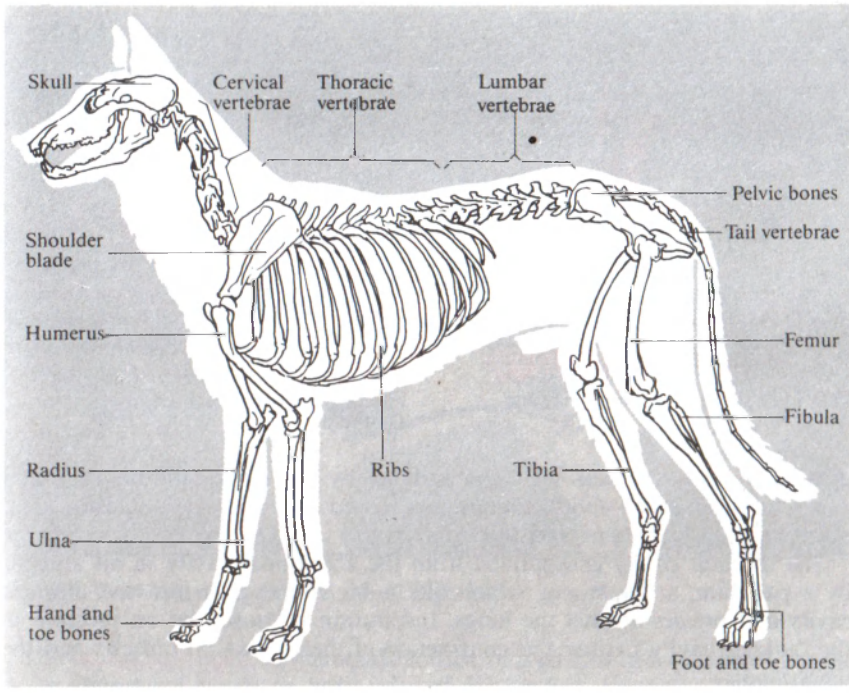


Fig. 143. Skeleton of a dog. Diagram

tongue, the jaws bear teeth. Animals determine the taste of the food with their tongue, whose surface is covered with numerous papillae, containing sensory nerves. The food is shifted in the mouth cavity by the tongue. The *saliva* that is secreted by the *salivary glands* moistens the food. Digestion of food is initiated by the saliva.

The teeth of mammals, unlike the teeth of the majority of reptiles, have *roots* that are fastened in bony sockets in the jaws. Each tooth consists of a special substance, *dentin*, and is covered externally with firm *enamel*. The teeth of mammals differ in structure, depending on their purpose. Chisel-shaped *incisors* are in the front part of the jaws, and then the large *canines* follow. The *molar teeth* are arranged further back in the mouth. First, *milk teeth* appear in the young, and later they are replaced by permanent teeth.

A dog tears apart large pieces of meat by means of the sharp edges of the molar teeth. The rear molar teeth of a dog have blunt tops to grind plant food. A dog picks the remains of meat off the bones by means of small incisors.

The stomach of a dog, like in the majority of mammals, is a single-chambered one, the intestine consists of a coiled *small* and a *large intestine*, and a *rectum*. The first part of the small intestine is the duodenum. The food in the stomach and in the intestine is treated with the secretions of the

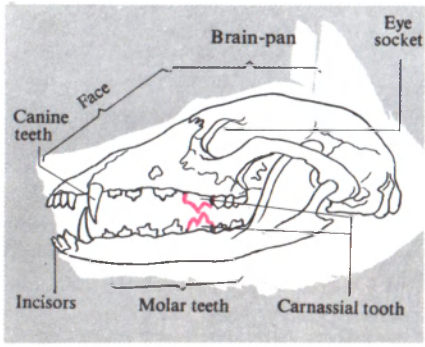


Fig. 144. Skull of a dog. Diagram

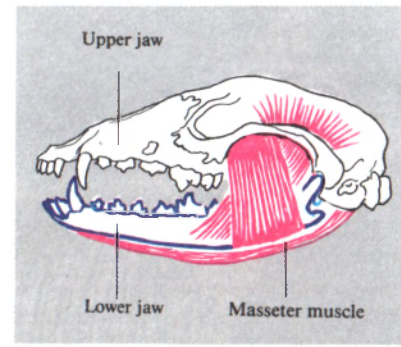


Fig. 145. Musculature of lower jaw. Diagram

digestive glands of their walls, as well as by the juices of the *liver* and *pancreas*. Undigested food remains are passed into the large intestine and excreted via the rectum and anal opening.

The thoracic cavity is separated from the abdominal cavity in all animals by a partition, a *diaphragm*, which like a big dome goes into the thoracic cavity and presses against the lungs. Inspiration is caused by an increase of the thoracic cavity's volume at contraction of the intercostal muscles and the diaphragm.

The ribs move forward and to the side, and the diaphragm changes its shape from a convex one to a flat one. At this moment air is charged into the lungs under the effect of atmospheric pressure. When the ribs lower, the thoracic cage contracts and the air is expelled from the lungs, thus expiration occurs.

The heart of a mammal is four-chambered, consisting of two auricles and two ventricles. The blood flows through two circulatory cycles: the systemic circulation and the respiratory circulation.

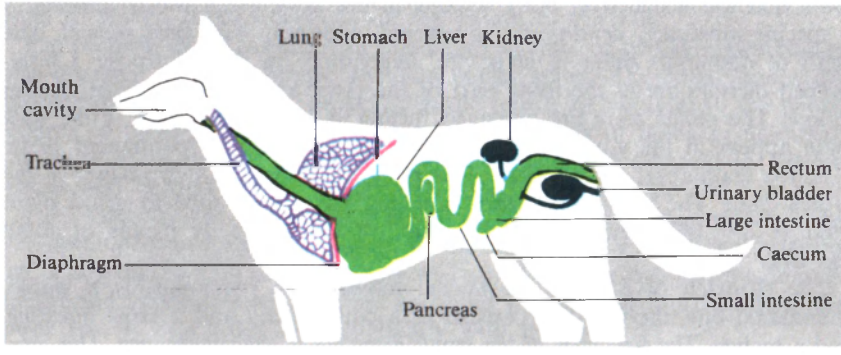


Fig. 146. Digestive, respiratory, and excretory systems of a dog. Diagram

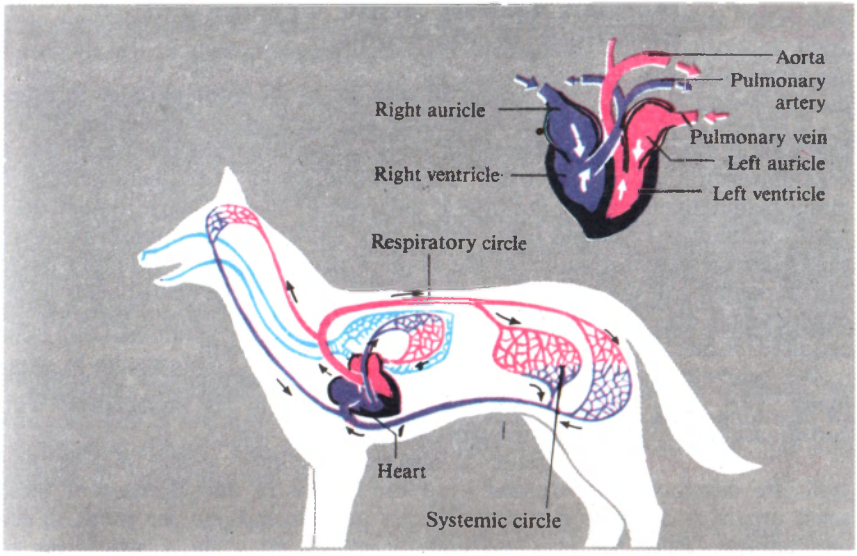


Fig. 147. Circulatory system of a dog. Diagram

The excretory organs of mammals consist of a pair of bean-shaped kidneys in the abdominal cavity on both sides of the lumbar vertebrae. The forming urine flows in two ureters into a single urinary bladder and is excreted periodically via an urethra.

Metabolism occurs in mammals at a high rate, owing to the comprehensive development of the respiratory and circulatory systems. Like in birds, the body temperature of mammals is constant, though it is lower by several degrees. The normal body temperature of a dog is 37-38 °C.

? △

1. Divide the section into parts and give a title to each one.
2. What new zoological terms have you learned in this section?
3. What are the structural parts of the vertebral column, fore and hind limbs in the mammals? (Use Figure 143 in your answer.)
4. Use Figure 144 to speak about the structure and purpose of various teeth of a dog.
5. What is the difference between a mammalian heart and the heart of other vertebrates?

■ Talk about your observations of the movements of a dog or a cat when it runs, leaps, and eats food.

2.63 Nervous System, Sense Organs, and Behaviour of Mammals

The brain of mammals consists of the same parts as in other vertebrates. However, the structure of the cerebrum of the forebrain is more complex. The outer layer of the cerebrum consists of nerve cells that form the cerebral cortex. The cerebral cortex of the hemispheres in many mammals, including the dog, is enlarged to such a degree that it does not form an even layer and forms folds, gyri. The greater the number of gyri, the better the cerebral cortex of the brain is developed, and the more nerve cells it contains. If the cerebral cortex is removed from the hemispheres in an experimental dog, the animal preserves its main instincts, but it loses all the acquired habits and new conditioned reflexes never form.

The cerebellum is well-developed and, like the hemispheres, it contains many gyri. The development of the cerebellum is associated with coordination of complex movements of mammals.

SENSE ORGANS. The organs of olfaction, audition, vision, taction, and taste are developed in mammals, but the degree of development of these sense organs is different in various species and depends on the mode of life and habitat. Thus, the eyes are underdeveloped in a mole, who lives in underground passages in total darkness. Dolphins and whales hardly discriminate odours. The majority of terrestrial mammals possess a very keen sense of olfaction. It enables predators, including dogs, to follow the scent of the prey; herbivorous animals sense from afar an enemy stealing up; animals of the same species find one another by their scent. Audition is also well-developed in the majority of mammals, which is assisted by the helices that pick up sounds and are very active in many animals. Animals who are active at night possess very keen hearing. Vision is less significant for mammals than for birds. Many animals don't discriminate colours. Only monkeys see the same range of colours as man.

Special long and rigid hairs (so-called "whiskers") are the tactile organs. A greater number of these hairs are near the nose and the eyes. Bringing its head near an object, the mammal smells, examines and touches it simultane-

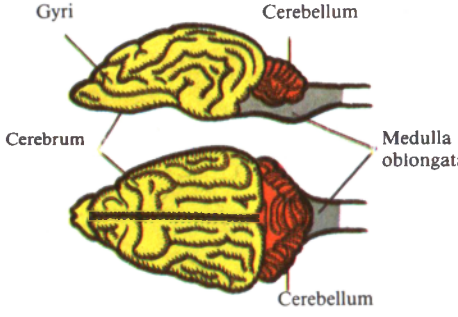


Fig. 148. Brain of a dog. Diagram

Fig. 149. Sensory hairs of a cat

ously. The main tactile organs of monkeys, like in man, are the fingertips. The sense of taste is especially well-developed in herbivorous mammals, owing to which they distinguish easily edible plants from poisonous ones.

The behaviour of mammals is no less complex than in birds. Alongside complex instincts, it is conditioned greatly by higher nervous activity, which is based on the formation of conditioned reflexes. Conditioned reflexes develop very easily and rapidly in species with a well-developed cerebral cortex of the brain hemispheres.

The young of mammals recognize their mother from the very first days of their life. Growing up, their individual experiences of contact with the environment become richer. The games of young animals such as struggling, mutual pursuit, leaping, running, serve as good training and help to develop individual methods of attack and defense. These games are characteristic only of mammals.

Mammals continuously develop new conditioned reflexes, because the environment is changeable. They lose reflexes that are not reinforced by conditioned stimuli. This feature of mammals enables them to adapt well and rapidly to environmental conditions.

? 1. What are the specific features of the structure of a mammalian brain?

△ 2. The coloration of the majority of mammals is brown, grayish, or black, and only some monkeys have bright blue, or crimson portions of the skin on the head and other parts of the body. What specific feature of vision can this be associated with?

3. It is known that domestic and tamed wild mammals yield easily to training. What specific features in their nervous system does a trainer use?

■ Observe what sense organs help a dog to find hidden food, or a stick hurled to some distance.

2.64 Reproduction and Development of Mammals

REPRODUCTIVE ORGANS. The reproductive organs of mammals are distinguished by certain specific features, owing to viviparity. The ovaries of the female are small, the ova developing therein are microscopically small (with a maximal diameter of 0.1 to 0.2 mm) and contain almost no yolk. Mature ova enter the oviduct where they are fertilized. Both oviducts open into a special organ of the female reproductive system, the uterus, which exists only in mammals. The uterus is a muscular sac, whose walls can stretch greatly. The dividing ovum attaches to the wall of the uterus and subsequent development of the fetus occurs in this organ.

DEVELOPMENT. Envelopes are formed around the embryo that fuse on one side into the wall of the uterus. In this place, which is called *placenta*,

the blood vessels of the mother contact closely with the blood vessels of the fetal envelopes. The embryo is joined to the placenta via an *umbilical cord* with blood vessels running inside it. Nutrients and oxygen pass from the mother's blood into the blood of the embryo via the walls of the vessels in the placenta, and carbon dioxide and other harmful products of vital activity are eliminated from the embryo in the opposite direction.

At the first stages of development of a mammalian embryo it has a notochord, gill slits, and other features of lower chordates. Continuously receiving nutrients from the mother, the embryo grows and stretches the walls of the uterus. The period of intrauterine development (gestation) is different in animals of various species and depends mainly on the size of the animal. Thus, gestation is 11-15 days in hamsters and mice, two months in a dog, and almost 1.5 years in an elephant.

PARTURITION. Parturition (or labour) starts at the end of the gestation period, and the fetus is ejected via the genital opening owing to contractions of the uterine muscles. The newly-born young inspires air for the first time, its lungs spread, and it begins to breathe independently. Then the umbilical cord breaks, or the female bites through it. The number of young in one litter (born simultaneously) is different in animals of various species. Large mammals usually give birth to 1 or two young ones, animals of average size have from two to five offspring in the litter, while species of small animals may give birth to very many (for example, a rat has up to 16 young in a litter).

Fig. 150. Horse with a foal

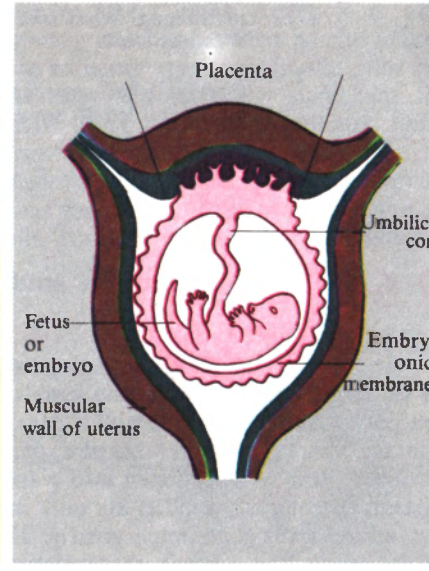


Fig. 151. Position of fetus in uterus. Diagram

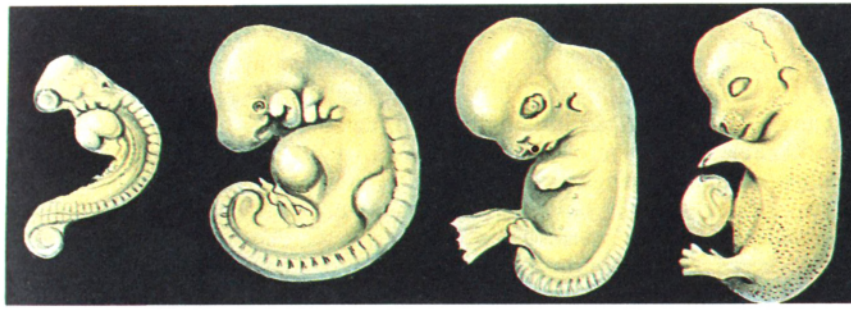


Fig. 152. Stages of development of mammalian fetus. Diagram

Nursing young with milk is one of the characteristic features of all mammals (hence the name of this class). *Milk* is formed in the *mammary glands* of the female, which occur usually on the chest or the belly. The ducts of the mammary glands open externally by little openings at the tip of the nipples, whose number varies (from 2 to 22), depending on the fertility of the species. A domestic dog, who gives birth to 3-8 puppies, has eight nipples.

The mammary glands start to produce milk by the time of parturition. It possesses high nutritiousness and contains all the substances necessary for feeding the young: water, fats, proteins, carbohydrates, vitamins, and mineral salts. The white colour of the milk is due to the presence of microscopic drops of fat in its composition. This fat is digested easily and is assimilated in the organism of the young.

The female nurses her offspring at the beginning only with milk. When the young grow up a little, they start to feed on regular food.

CARE OF YOUNG. The young of all the predators, many rodents and other small mammals are born blind, sometimes naked. The female of these species builds a nest or a den before parturition. She warms and nurses her offspring, licks them, cleans the shelter. The young of the majority of herbivorous mammals are born quite developed and can follow their mother a few hours later. Care of the young (besides nursing with milk) consists mainly in its protection. Females of all mammals display great activity in case of direct danger threatening her offspring, and protect them, often at the risk of their own life. The male, as a rule, doesn't take care of the offspring. Pairs form, usually, only for the period of reproduction, rarely for several years (for example, wolves).

?

1. When and how do nutrients and oxygen enter the body of a mammalian embryo?
2. What do the presence of gill slits and the notochord in the embryo of mammals at the early stages of development indicate?

△

3. On the basis of your own observations, talk about how mammals care for their young.

2.65 Origin of Mammals. First Beasts

SIMILARITIES AND DIFFERENCES BETWEEN MAMMALS AND REPTILES. The structure of the skeleton, musculature, organs of digestion, respiration, blood circulation, and excretion displays considerable resemblance between mammals and reptiles. It is easy to see features in the coverings of mammals that are common to those of reptiles (horny scales on the tails of some mammals, presence of claws). Undoubtedly, structural resemblance points to a certain relationship between these classes of vertebrates. However, there are differences, such as the warm-bloodedness of mammals, the complicated structure of the heart and central nervous system. Furthermore, mammals differ from reptiles by viviparity and the presence of mammary glands.

ORDER: MONOTREMATA (FIRST BEASTS). Several species of animals, so-called first beasts, occur in Australia and on the islands of New Guinea and Tasmania. Their structure and specific features of reproduction are intermediate between reptiles and mammals. Scientists assign the duck-billed platypus (!) and the echidna (or the spiny anteater) (!) to this order.

A duck-billed platypus is a semiaquatic animal. Its body length is slightly in excess of 50 cm and is covered with short brown hair. The jaws are shaped to form a duck-like flattened horny bill. The short limbs are webbed between the digits, the tail is flattened. Duck-billed platypuses hide in burrows on the banks of water bodies, they feed in water on crustacea, mollusks, aquatic larvae of insects, and worms. The echidna (several species are known) is a terrestrial animal about 40 cm long. It looks like a hedgehog, because it is covered with prickly spines. The thin, sharpened snout of an echidna is covered with a horny integument. A little mouth is at the tip of the snout. The digits of the echidna have powerful claws that it uses to dig up anthills to reach the ants. An echidna can move stones aside with its powerful limbs when searching for insects and earthworms.

The first beasts have a cloaca, like reptiles. They lay eggs closed in a soft shell envelope. The duck-billed platypus hatches the eggs in an underground nest, and a female echidna carries the eggs in a special pouch on her belly. The emerging young are nursed by the first beast with milk, therefore they

Fig. 153. Duck-billed platypus

Fig. 154. Echidna

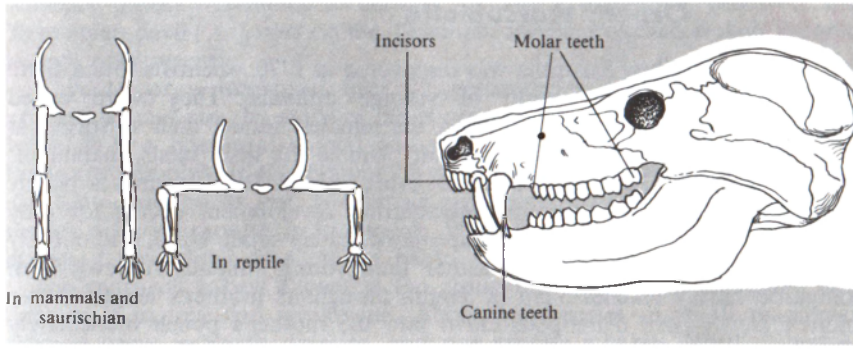


Fig. 155. Position of body and limbs

Fig. 156. Skull of a saurischian

are attributed to the class of mammals. However, the mammary glands of the duck-billed platypus and the echidna are underdeveloped and have no nipples. The dense milk flows down the fur and the young lick it off.

The body temperature of the first beast is not as high as in other mammals, reaching only 25-30 °C. It rises or drops by 5-6 °C, depending on the ambient temperature. The first beasts resemble in this respect reptiles, whose body temperature is also dependent on the ambient temperature.

Fossil ancestors of mammals, dentate saurischians, lived from 200 to 230 million years ago. Scientists have determined by the fossils of their skeletons that the legs of the animals were not set on the sides but were under the body, like in mammals. The teeth in these creatures were divided into incisors, canines and molars. The first representatives of ancient mammals possessed the features of both reptiles and mammals. Mammals had certain advantages as compared to reptiles, first and foremost a highly developed brain, viviparity, and the ability to nurse the young with milk. This contributed to a higher survival rate of the offspring, and the constant high body temperature made it possible for the mammals to settle in regions that were inaccessible to reptiles (for example, in the tundra, Arctic regions, high up in the mountains).

? △

1. Name the common features in the structure of primitive beasts and reptiles.
2. What features of primitive beasts make it possible to relate them to mammals?
3. Use Figures 143, 144, and 155, 156 to compare the skeletons of the limbs and teeth of saurischians and the dog.
4. Read the brief characteristics of the classes of reptiles and mammals in the appendix (pp. 211–212). What are the similarities and differences between these groups of animals?

2.66 Order: Marsupialia

When Australia was discovered in 1770, scientists found there a whole world of strange animals. They were called marsupials, because in most of them the females nursed their offspring in a special abdominal pouch (marsupium). Unlike the first beasts, marsupials did not lay eggs. They gave birth to living young. The placenta is poorly developed in these animals and intrauterine development occurs for only a short time, the young are born disproportionately small, blind, and entirely naked. They resemble embryos rather than young animals. A newly-born kangaroo hardly reaches 3 cm in length, though its mother's length is two metres. Newly-born marsupials crawl into the mother's pouch immediately after birth and attach themselves to the teats.

They are unable to suck at the beginning and the mother, contracting special muscles in the teat, periodically injects milk into their mouth. As the young grow, a hair covering develops and their eyes open. They can leave the pouch, but they get into it again in case of danger, to get warm, or to suck milk.

The species of marsupials are very diverse. Externally and by their mode of life many of them resemble well-known animals which occur on other continents. Moles burrow in the fields of Australia, but they are marsupial moles, who greatly resemble European moles. Various species of long-tailed and striped field marsupial mice occur in Australia. Marsupial rats and marsupial cats are also found in Australia. Marsupial squirrels and pouched martens occur in Australian forests. Jerboa-like marsupials are found in the steppes and deserts. There are also marsupial anteaters (!). A marsupial

Fig. 157. Kangaroo

wombat greatly resembles a marmot. A small marsupial predator, the Tasmanian devil (!), occurs on the Tasmania Island. Pouched wolves became extinct only recently.

A koala, or a marsupial bear (!), resembles a plush toy-bear in its appearance and size. Its mode of life is quite different from the habits of our bears. It is a nocturnal animal and feeds only on eucalyptus leaves. The koala sits immobile in the daytime on a tree branch, grasping it with a sharp and long claws on its feet. The female gives birth usually to one young and carries it for six months in the pouch. When the cub grows up, the mother carries it for a long time on her back.

The kangaroo is best known in the group of marsupial animals, and one can see it in any zoo worldwide. About 100 species of small marsupial animals occur in South America, and one species inhabits North America.

2.67 Order: Insectivora

SHREWS. Shrews resemble mice externally. The common shrew (!) is most widespread. Its small body is 7-10 cm long and is covered with dark-brown fur. The common shrew occurs in forests and meadows, but it can also live in steppes and the tundra.

The common shrew runs very fast despite its short legs. The little animal needs a lot of food owing to its great mobility. The weight of the food it eats every day exceeds its body mass by 1.5-2 times. When it is satiated, the animal rests for a short time, but when the food is digested, it starts to search for food again. Shrews are active the year round in all seasons. The shrew preys mainly on insects, finding the latter on the ground, in the forest litter, under the soil, and in other places that are difficult for insectivorous birds to reach. Shrews do much good by consuming vast quantities of harmful insects.

All the shrew's teeth are of similar structure. The teeth enable it to grab and crush its prey coarsely but the animal cannot chew it adequately. This

Fig. 158. Mole

Fig. 159. Hedgehog

feature is also characteristic of other insectivores that are related to the shrew, including moles and hedgehogs. The hemispheres of the brain in all the insectivores are developed poorly and have no gyri. Conditioned reflexes in insectivores develop slowly and poorly. Insectivores are very close to reptiles by these features.

COMMON MOLE. A mole lives all its life in burrows that it digs out. There are very many moles in the forest and forest-steppe zones, where they occur on meadows, in the fields, at the edges of forests, in orchards, and gardens. Fresh earth hills are found easily where the animal digs its underground galleries. The body structure of the mole is adapted for living underground and for digging. The body is stout and cylindrical, the ears are vestigal, the neck is very short. The mole digs the earth with its strong forelimbs, which are short but have wide spade-like paws with powerful claws. The mole uses its spade-like limbs to loosen the earth and throw it far behind itself. The mole's eyes are underdeveloped and are of a pinhead size, owing to the constant darkness in the underground dwelling. The animal searches for food by means of well-developed olfaction and taction.

The hair covering of the mole is short and velvety. When the mole moves forward in the burrow, the undercoat is pressed tightly against its body and protects the animal's skin from earth and moisture. The undercoat is pressed to the animal's body in the opposite direction when the mole moves backwards.

A mole is active all year round. It moves continuously through the passages that it digs in various directions. The passages have a length of several hundred metres and the mole eats the earthworms that it finds there, in addition to insects and their larvae. When the amount of food turns scarce, the mole digs new passages. Moles are hunted for their beautiful fur.

EUROPEAN HEDGEHOG. Many have seen a hedgehog under natural conditions and know its ability to roll itself into a ball in case of danger. The hedgehog is a nocturnal animal, and is quite voracious. Its diet consists principally of insects, especially beetles. When the winter season begins and the amount of available food is insufficient, the hedgehog hides in an earlier built shelter and goes into hibernation. The body temperature of the hedge-

Fig. 160. Common noctule

hog drops, it breathes rarely, the heart beats slowly and weakly, i.e. the entire organism is in a profound torpor till the beginning of the warm season.

2.68 Order: Chiroptera

ADAPTATION OF CHIROPTERANS TO FLIGHT. Representatives of chiropterans (for example, bats) are well adapted to flight, but the structure of their wing is different than that of birds. It is formed by leathery membranes stretched between the greatly elongated digits of the forelimbs and between those and the hindlimbs and the tail. Bats flap their wings in flight, their fingers spread apart, the flight web (chiropatagium, or wing membrane) stretches and the wing area increases. Like in birds, flapping flight necessitated in chiropterans the intensive development of the thoracic muscles; a keel is developed on the sternum.

ORIENTATION IN SPACE. While in flight bats find and adroitly catch with their mouth insects even when it is dark. Scientists have been interested for a long time in the ability of chiropterans to orient themselves in the darkness. In experiments, blinded bats never collided with tree branches and hunted just as successfully as those that could see. But, if the eyes of a bat were left open, and the helices and mouth were closed, the animal never even made an attempt to fly off into the air. It turned out that bats possess a remarkable ability to orient themselves in air by means of sounds of very high frequences that are not perceived by a human, i.e. with the aid of ultrasounds. Ultrasounds, generated intermittently by the animals, are reflected well from objects in their way and the keen ear of the animal perceives them in the form of an echo.

Bats are small chiropterans. The common noctule (!), long-eared bat (!), and others occur in our country, totalling about 40 species. Bats prey at nighttime and rest during the daylight hours in garrets, basements, hollows

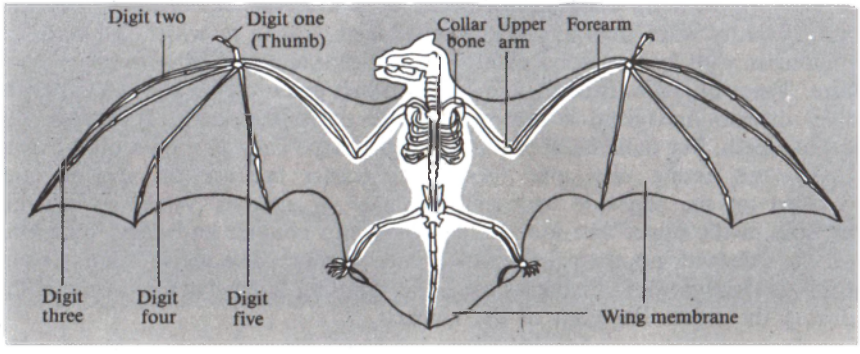


Fig. 161. Skeleton of a bat. Diagram

in trunks of trees, and in other secluded places, assembling sometimes in great quantities. Their hindlegs are effective grasping organs and are used for clinging to a perch from which the bats hang upside down when at rest. During rest in the daytime, the body temperature of the sleeping animals drops, respiration and blood circulation slow down.

The female gives birth usually to one naked and blind young. She hunts together with her young, who holds tight to its mother's body.

Long-eared bats go into profound and long hibernation in winter. The animals migrate in due time to their wintering grounds and hide in reliable shelters. The common noctule migrate to southern regions.

Superstitious people are afraid of bats for their strange appearance and concealed mode of life and make up many absurd stories. In fact, bats do much good by exterminating beetles, mosquitoes, and night moths. Bats should be attracted to settlements. Their shelters should be preserved, or artificial houses should be hung up like it is done for birds.

Not all bats feed on insects. A fish-eating bulldog bat, that catches with the claws of its hindlegs small fish on the water surface, occurs in Cuba and in tropical countries of America. Vampire (or blood-sucking) bats live in the jungles of South America. At night, with its blade-sharp incisors, the bat shears a piece of skin on the body of an animal and licks the dripping blood. Big fruit bats, having a wingspan up to 170 cm, occur in tropical countries and feed on the fruits of various plants.

△ 1. Use Figures 112, 160, and 161 to talk about the difference between the wings of a bat and a bird.

? 2. How do bats orient themselves when flying in darkness?

3. What is the benefit of bats?

2.69 Gnawing Mammals

SPECIFIC FEATURES OF TOOTH STRUCTURE. Feeding on solid food causes wear of the teeth. The incisors become more bluntly worn than any of the other teeth, owing to which the teeth of mammals, who feed on solid plant food, are characterized by a specific structure. These animals (rodents and lagomorphs) gnaw off pieces of food with their incisors and grind it thoroughly with the molar teeth. They have no canine teeth, but their incisors are big and sharp. They never become blunt, even when eating very solid food. This occurs because the incisors are covered on the top side with a thick layer of enamel. When biting, the incisors in the upper and lower jaws come into contact and grind off more on the side with no enamel (or where it is thinner). The incisors are always the same size no matter how strong the grinding is: they grow continually during the entire life span of the animal.

The red squirrel is widespread in the forests of the European and Asian parts of our country. A squirrel spends the majority of its time up in the trees, where it displays great talent in climbing with the aid of its sharp claws. The presence of a squirrel is manifested by the traces of its activity: cones, that have been gnawed all round to the very core, are scattered on the ground under fir-trees and pines. The squirrel gnaws off the scales to reach the seeds. Besides the seeds of coniferous trees, nuts and acorns, the animal also feeds on leaf buds, berries, mushrooms, and insects. In autumn a squirrel stores reserves for the winter. The squirrel rests in the hollow of a tree trunk, or in a nest that it builds itself. The female gives birth there to four-five young, and nurses them with milk for about 1.5 months. The squirrel is a valuable object of hunting.

Mouse-like rodents make up a numerous group of small and sometimes average-sized rodents, totalling about 1500 species. They include the well-known house mice and rats, the long-tailed and striped field mice, hamsters, voles (they resemble mice but have a shorter tail). The majority of mouse-like rodents are very fertile. They are of great significance in nature and in human economy because of their plurality. Some of them, for example, the muskrat, is prized for its beautiful fur (see Figure 179 on p. 188).

North America is the native land of the muskrat. It was brought to the USSR about 50 years ago and let free. It is one of the principal fur-bearing animals in our country today.

SIGNIFICANCE OF RODENTS IN NATURE AND FOR MAN. Some rodents (squirrels, muskrats) are prized for their fur, others (some mouse-like rodents) are the principal food for valuable fur-bearing animals. Many rodents (little sousliks, common voles) cause damage to grain crops, house rats and mice destroy and spoil reserves of foods in warehouses and in

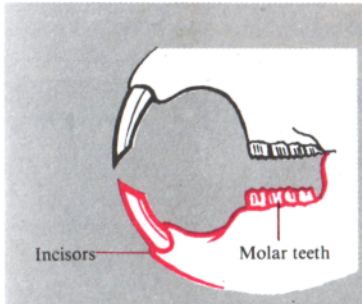


Fig. 162. Teeth structure of a rodent. Diagram

Fig. 163. Skull of a rodent. Diagram

human dwellings. Long-tailed field mice eat the seeds and sprouts of valuable trees at tree nurseries and plantations.

The role of rodents is very great in spreading many dangerous diseases of man and domestic animals. Infectious jaundice is communicated to man by direct contact with rodents, or via products that they have damaged. Mouse-like rodents, sousliks, and some other representatives of this group may carry the plague, encephalitis, and other diseases that can be communicated to man by blood-sucking arthropods (for example, fleas, mites).

A struggle is carried on against harmful rodents. They are exterminated, caught by means of various mouse-traps and presses, poisoned bait is scattered near their burrows. It is very important to protect birds of prey and mammals, who feed on rodents.

Order: Lagomorpha

HARES. The white hare and the European hare are most widespread in the USSR. The white hare inhabits the northern forests and the tundra. It is adapted well to a long winter. The hare is hidden in the snow by its fluffy white fur which grows instead of the summer brown fur. Its wide paws are covered with thick hair. The locomotion of a hare is rapid, and it does not fall through loose snow.

Two or three times a year a female white hare (doe-hare) gives birth to a litter of 2 to 6 young hares, who are covered with fur. They see and are capable of locomotion.

Immediately after birth, the young hares suck thick and fat milk to their fill, scatter and hide in secluded places. The female finds them two-three days later and nurses them again. By visiting the young hares rarely, the female attracts fewer predators, thereby preserving her offspring. The young hares grow rapidly: in five to ten days they start an independent life, and can reproduce by the end of the first year.

RABBITS. Wild rabbits occur in our country in the Southern Ukraine,

Fig. 164. Hare

Fig. 165. Rabbit

settling in hilly areas and ravines. They dig out numerous burrows where they hide in case of danger; they feed at night near the burrows. The female (doe-rabbit) builds a warm nest in the burrow. The female gives birth to 4-12 young rabbits usually three or four times a year. Unlike young hares, rabbits are born blind, naked, and helpless.

Man domesticated the wild rabbit and developed many breeds of domestic rabbits for the production of tasty meat, fells and wool (rabbit down).

2.70 Order: Carnivora

SIGNIFICANCE OF CARNIVOROUS MAMMALS. Predators are indispensable members of every biological community, and serve as regulators of the number of other animals. Predators primarily attack abundantly breeding species (for example, mouse-like rodents), or kill a sick animal. Therefore, it is unadvisable to exterminate predators completely. Many predators are protected.

FAMILY: CANIDAE. We studied earlier one representative of this family, the domestic dog. All canids have an elongated muzzle, which is associated with intensive development of the nasal cavities, olfactory organs (organs of smell). Dogs find prey using their sense of smell and, discovering the prey's scent, take off in pursuit. The saying "Feet feed the wolf" is true for all the representatives of this family: foxes, Arctic foxes, etc. The wolf lives in the tundra, forest-steppe, also in steppes, and semideserts. Wolves prey on deer, elks, wild boars, but also feed on small animals, ranging from hares to

Footprint of a wolf

Footprint of a dog

Fig. 166. Wolf

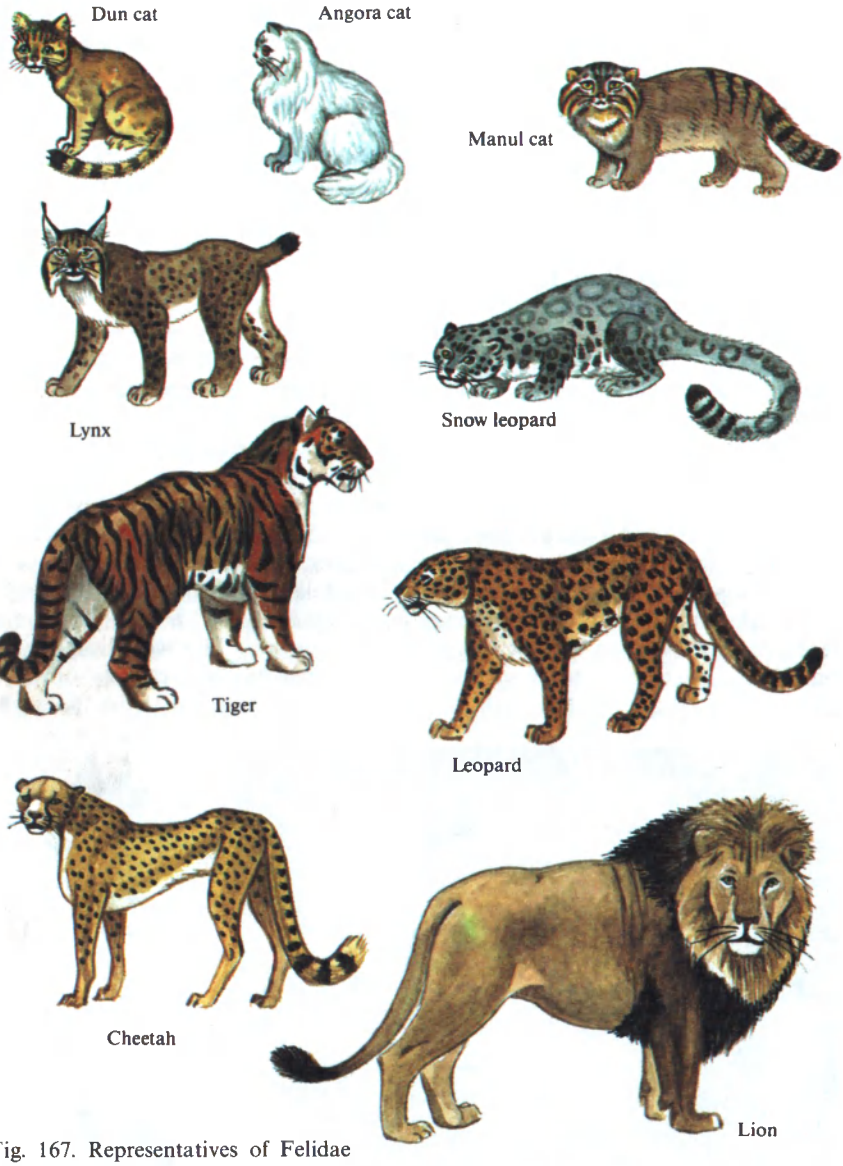


Fig. 167. Representatives of Felidae

mouse-like rodents. The wolves hunt in packs, and only rarely alone. It is easier for a pack to kill a big animal, escape danger, protect a hunting territory from other wolves. Prolonged loud howling betrays the presence of predators. By altering the intonation of their voice, they inform the other members of the pack about the presence of prey, people, and strange wolves.

Wolves are shrewd and strong predators, displaying great inventiveness in finding food and at escaping pursuit. Wolves are harmful in regions with developed cattle-breeding. Therefore, their number is continuously under human control. When necessary, battues are organized to kill the wolves, traps are set.

FAMILY. FELIDAE (CATS). All cats are alike in their appearance, though they differ greatly in size. This family includes the domestic cat and such big beasts as the tiger and the lion. A felid has a round head with big eyes that see keenly in the daytime and at night. They have a very keen ear, while their sense of smell is poorly developed. Cats usually lie in ambush for their prey, or steal up on it with soft and silent steps. Their claws are retractible, they draw upward during walking and, therefore, neither knock on the ground, nor become blunt. All cats are clean animals, they continuously "wash" themselves, therefore, they neither produce any odour, nor betray themselves in ambush. They allow the prey to get near and then make a sudden leap at it with their supple and strong body, inflicting deep wounds with their sharp claws. All cats feed only on animal food.

Several species of wild cats (!) of the family Felidae occur in the USSR, including the lynx (!), cheetah (!), leopard (!), snow leopard (!), and tiger (!). They all have become so rare that they need to be protected.

The domestic cat evolved from the wild Egyptian cat, which lives today in Africa. Man domesticated the cat a long time ago, but there is little difference in the appearance of a domestic and a wild cat. There are only

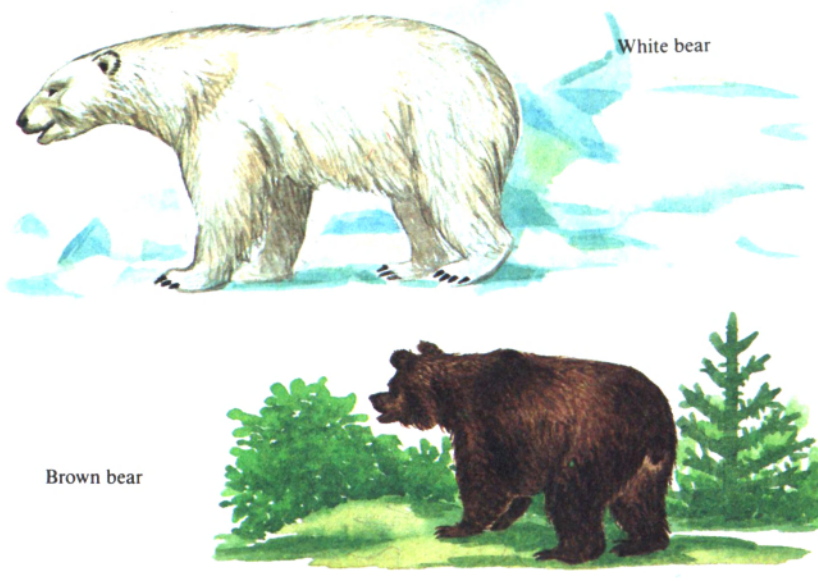


Fig. 168. Brown and white bears

a few breeds of domestic cats. The Angora cat is well-known, having long beautiful fur, as is the Siamese cat with short, tightly fitting fur.

FAMILY: MUSTELIDAE. Mustelids are distinguished from other predators by smaller body sizes. The marten, sable, weasels, and polecats are extremely mobile and adroit predators with a long and lithe body on comparatively short legs.

The sable occurs from the Urals to the Pacific Ocean and is one of the most valuable fur-bearing animals. It is hunted for its beautiful dark-brown fluffy and extremely thick winter fur. A sable preys on its principal food, rodents, on the ground, but it climbs trees too. The sable also eats cedar nuts, berries and insects, and preys on birds. As the majority of predators, the sable preys and breeds offspring on the territory it occupies, protecting it zealously from other sables. Owing to destructive extermination at the beginning of this century, the sable was on the brink of total extinction.

FAMILY: URSIDAE. This family includes the biggest predaceous beasts. Unlike other representatives of the order Carnivora, bears (!) don't walk on their tiptoes, but step on the whole sole.

? 1. Why do felids have a round head? (Compare it with the head of canids.)
△ 2. What is the difference between the methods of hunting a wolf and a tiger?
3. Are predatory mammals beneficial? What is their benefit?
4. What species of bears do you know?

2.71 Marine Animals

ADAPTATION OF MAMMALS TO AQUATIC LIFE. The representatives of two orders: Pinnipeda and Cetacea are marine animals. The ancestors of marine animals were terrestrial dwellers, close to ancient (primitive) predators. This can be judged because of the resemblance between the teeth of predators and pinnipeds. Life in an aquatic environment left a profound imprint on the structure of marine animals. Their limbs modified into organs of locomotion in water – flippers – resembling the externally paired fins of fish. The body shape of marine animals is also fish-like, streamlined. The hair covering does not protect them in water from cooling, therefore marine animals have a thick layer of fat beneath the skin that helps to maintain a constant high body temperature.

ORDER: PINNIPEDIA. Pinnipeds (seals, walruses, fur seals, etc.) spend the greater part of their life in the water. They obtain food, rest, and even sleep there. They return to land, or climb up on ice-floes to breed and molt.

The Greenland seal occurs in Arctic seas. The seals spend the greater part of the year in the open sea, feeding on fish, mollusks, and crustacea. In winter herds of seals approach the shores and crawl out on level ice fields. The female gives birth there to a single big young with open eyes. The young

Fig. 169. Greenland seals

seal is protected from frost by a coat of thick white fur, which makes it invisible in the snow. The herd migrates to the North at the beginning of spring. Seals are hunted for their fells and fat.

Fur seals (!) occur in Far East seas. The body of the seal is covered with thick fur, and has thick waterproof undercoat. Big herds of fur seals breed on the shores of islands at the beginning of summer. The female gives birth to a single young, who is covered with black hair. In autumn, when the young grow up and learn to swim, the fur seals leave the islands till the next spring. The seals are prized for their valuable fur.

Fig. 170. Fur seals

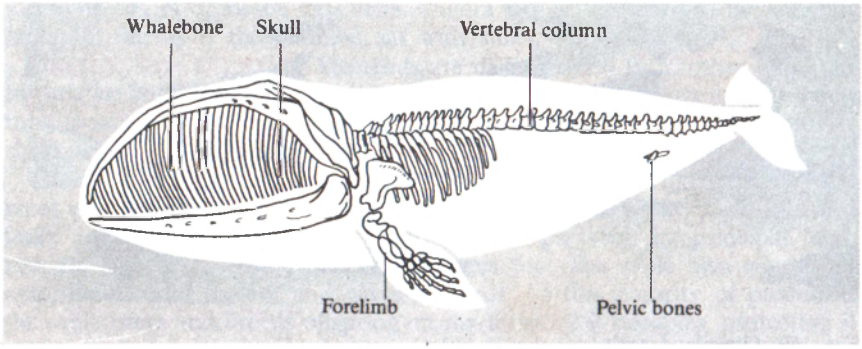


Fig. 171. Skeleton of a whale. Diagram

ORDER CETACEA. Representatives of this order, whales and dolphins, never go ashore, even their young are born in the water. The body of cetaceans is hairless. They move in water by means of the tail fin and a pair of forelimbs that have modified into flippers. Two small bones at the pelvis make it possible to assume that the ancestors of cetaceans had hindlimbs too. The young of cetaceans are quite well developed at birth and can follow their mother immediately.

The blue whale (!) is the largest living mammal. Some specimens reach a length of 30 m and a mass of 150 t, corresponding to the mass of at least 40 elephants. The blue whale is toothless. It feeds on small aquatic animals, principally on crustacea. Numerous elastic fringed horny plates, whalebone, suspend from the upper jaw of the animal. Taking water into its enormous oral cavity, the whale filters it through the plates in its mouth and swallows the crustacea that remain there. A blue whale eats from two to four tons of food daily. The layer of fat beneath the skin, or blubber, reaches a thickness of 30-50 cm in large whales. This main product of whaling is used in the food and perfume industries.

Limits have been imposed worldwide on whaling, because the number of whales has diminished. An international organization controls the observance of whaling rules. The USSR is a member of this organization.

Dolphins, like cachalots, are toothed cetaceans. The common dolphin (!) occurs in Northern and Far East seas, also in the Baltic and Black seas. Its length is a maximum 2.5 m. Its slim body is black on the top, and white on the belly and sides. The elongated jaws of the common dolphin have more than 150 teeth of similar conical shape. The dolphin uses its teeth to grab and hold a fish, which it swallows whole. The animal finds prey by means of ultrasounds. The dolphin produces clicking sounds in the water, or intermittent whistles of high frequency, and the echo, reflected from an object, is perceived by the organs of audition.

Dolphins communicate with one another by means of sound signals, owing to which they assemble rapidly when one of them detects a shoal of fish. If an accident happens with a dolphin, others come to its aid the

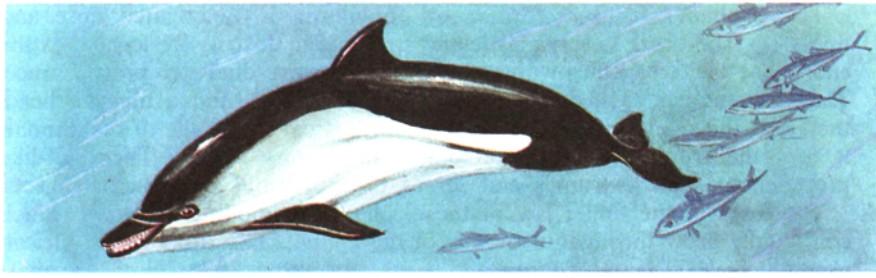


Fig. 172. Dolphin

moment they hear alarming signals. The brain of dolphins is of a complex structure, its cerebrum contains a plurality of gyri. Dolphins are tamed rapidly in captivity and are trained easily. It is forbidden to hunt dolphins in the USSR.

? 1. What features in the structure of pinnipeds and cetaceans are associated with the aquatic mode of life?
△ 2. What proof is available of the origin of pinnipeds and cetaceans from terrestrial mammals?

2.72 Ungulates

ADAPTATION OF UNGULATES TO LIVING CONDITIONS. Ungulates make up a large group of mammals that have horny *hoofs* instead of claws at the ends of their digits.

The majority of ungulates are herbivorous. They run to escape from predators. The young are born with open eyes, and a hair covering. They can follow the herd a few hours after birth.

Order: Proboscides

Elephants are the largest terrestrial animals. They range throughout tropical forests: the African elephant is indigenous to Central Africa, and the Indian elephant occurs in South and South-East Asia. Each one of the five digits on the large columnar legs is covered with a thin horny hoof. The main weight of the body rests on a hard and elastic pad located under the 'hand' and extending over the underside of the foot, owing to which the locomotion of an elephant is rapid and noiseless, despite its bulky body. The thick skin of the elephant is sparsely covered with hair and protects the animal from the bites of blood-sucking insects and other damage.

The elephant's trunk is formed by an enormously elongated nose and upper lip. The trunk is very elastic and strong. The nostrils are located at the end of the trunk together with a fleshy and sensitive digit-like protuberance. The elephant has a short neck, which is not mobile, and a massive head, therefore, the significance of the long trunk is great in the life of the animal: it uses the trunk to bring food and water to its mouth. The digit-like protuberance at the trunk's end serves to detect and grab small objects.

The tusks in the upper jaw of the elephant are modified incisors, which continually grow throughout the life of the animal. The tusks of an African elephant reach a length of 2 m and a mass of about 80 kg. Both the male and female have tusks. Only the male Indian elephant has tusks. Beautiful carved articles are made of ivory, which is the very hard substance of the tusks. Elephants were killed barbarously for the sake of these tusks and today their number is greatly reduced.

Besides the tusks, the elephant has a tremendous molar tooth in each half of the upper and lower jaws, and no canines. The elephant uses its molar teeth to grind daily several dozen kilograms of coarse plant food: branches and leaves. The old worn teeth are replaced every 10-15 years by new ones. The growing tooth pushes out the old one and takes its place gradually. An elephant replaces its teeth six times during its life. An elephant lives for 60-80 years.

The cow gives birth once in 3-4 years to a single calf, which is covered with hair. The calf can follow its mother a few days after birth. Indian elephants can be tamed but, as a rule, they don't breed in captivity. The elephants are obedient and do various hard tasks in captivity.

Order: Artiodactyla

Artiodactyles (even-toed ungulates) have an even number of toes (2 or 4) on their feet – a pair or two pairs. Each toe is covered with a thick horny hoof, like with a shoe, protecting it from hitting the ground. This order includes pigs, hippopotami, deer, giraffes, and a large group of hollow-horned animals, for example, antelopes, goats, sheep, and oxen.

Even-toed ungulates, who move around on soft soil, for example, reindeer or elks, have wide, flat hoofs that increase the area of the supporting surface. Goats and chamois, who spend their life in the mountains, on the contrary, have narrow hoofs with a solid edge. The animals use them to rest against tiny projections on rocks, to leap across rocky streams.

Horns on the head are characteristic of many undulates. Thus, the males of deer and elks yearly shed their antlers that grow out again in spring. The horns of the majority of agricultural animals, for example, cows and goats, grow all their life and are never shed. All wild ungulates have a complex multichambered stomach. The latter is best for processing herbivorous food which is hard to digest.

SPECIFIC FEATURES OF DIGESTIVE SYSTEM. A pasturing cow cuts off the grass with its lips, incisors, and canines in the lower jaw that resemble

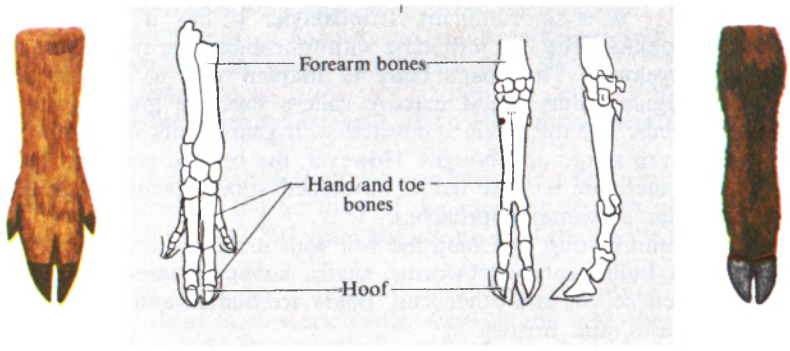


Fig. 173. Structure of limbs of an artiodactyle. Diagram

the incisors. There are neither incisors, nor canines in the upper jaw. The swallowed food passes through the esophagus into a multichambered stomach. At first it enters the biggest chamber, the rumen (paunch), wherein digestion is initiated under the effect of saliva and where microorganisms and protozoa are active. The food then passes to the next chamber, the reticulum (the name is associated with the honeycomb structure of the walls in this chamber), and thence it is regurgitated through the esophagus into the oral cavity. When watching a cow at rest, one will see that it is ruminating all the time (hence all artiodactyles are called ruminants, except pigs and hippopotami). The molar teeth of ruminants have wide flat surfaces, that a cow uses to grind the regurgitated coarse food to a pulpy mass, which is swallowed again. The food passes now into the third chamber, the omasum (psalterium or manyplies). The walls of this chamber have many folds, resembling pages in a book. The cellulose is digested finally in this chamber and the food mass passes into the last chamber of the stomach, the abomasum, wherein the protein is digested under the effect of digestive juices.

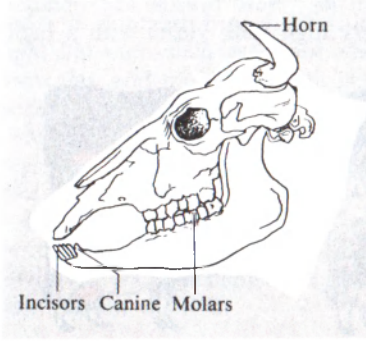


Fig. 174. Structure of a cow's skull. Diagram

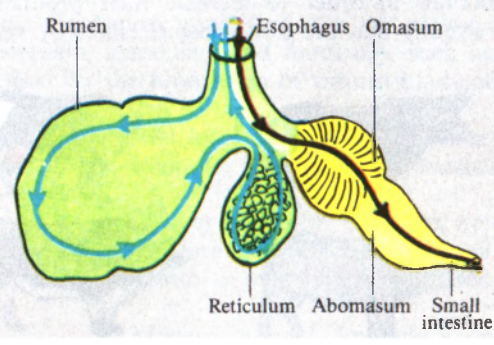


Fig. 175. Structure of a cow's stomach. Diagram

A wild boar is a nonruminant artiodactyle. It has a simple single-chambered stomach. The legs terminate with four digits, the two middle ones being well-developed. The boar's body is adapted well to locomotion in impassable regions: humid and marshy valleys that are grown over with shrubs and reeds. The thick skin is covered with guard hairs that protect the body from sharp spines and boughs. However, the bristles conserve warmth very poorly, therefore a boar has a developed subcutaneous layer of fat, which increases as winter approaches.

A boar is omnivorous: grubbing the soil with its snout and tusks, it digs up roots and bulbs, eats earthworms, snails, larvae of insects, mouse-like rodents, collects acorns and other fruit. Boars are hunted and are valued for their meat, hides, and bristles.

? △
1. What mammals belong to Artiodactyla?
2. Where does a boar live and what does it feed on?
3. Use Figures 163 and 174 to compare the dentition of rodents and artiodactyles. Note the differences and the similarities between them.

2.73 Animal Husbandry

SIGNIFICANCE OF ANIMAL HUSBANDRY. Products obtained by breeding agricultural animals provide man with valuable foods: milk, meat, and fat. The industry makes use of leather, wool, and bristles also. Besides that, certain fodder is made of the by-products and waste of animal husbandry for example, meat-bone meal, medicinal drugs, and fertilizers.

Animal husbandry, as a branch of agriculture, appeared in ancient times when man started to tame wild animals, domesticate and use them for his needs. By tenacious efforts man modified the nature of the domesticated animals in order to increase their productivity. New breeds are created currently that are distinguished either by very high milk yields with a high

Fig. 176. Cattle breeds

fat content, or by highly nutritious meat, or by other qualities that are useful for man. Various breeds of horned and small cattle as well as pigs have developed to become the major agricultural animals.

DIVERSITY OF BREEDS OF AGRICULTURAL ANIMALS. Various breeds of horned cattle were reared by man in ancient times when domesticating wild animals.

Cattle breeds have evolved from representatives of wild oxen. The wild ox, tur, which occurred on the territory of the southern steppes in our country and became extinct about 300 years ago, was one of the ancestors of modern breeds.

There are four principal groups of cattle breeds existing today: dairy, meat-and-dairy, meat, and work cattle. One of the best dairy breeds for northern territories, Kholmogorskaya, evolved in the 17th century in the Kholmogorsk region of the Arkhangelsk district.

The Yaroslavskaya breed is widespread in the temperate zone of our country, and the red steppe breed in the southern regions.

The Simmental breed, that was bred in Switzerland, and is widespread now in many countries, and the Kostroma breed are examples of the meat-and-dairy breed.

The meat breeds are raised mainly for the production of meat, because their milk production is rather low.

Work breeds of cattle were used in this country before the Great October Socialist revolution for ploughing and for drawing heavy loads. These breeds have lost their significance currently in the USSR because of mechanization, but in some countries, especially in South Asia, work cattle (for example, buffaloes) are used quite intensively.

Many valuable breeds of small cattle, for example, sheep, are reared in the USSR. Breeds of the latter include: merino, Romanovskaya, Karakul, Tsigeian. Sheep are unpretentious as far as food is concerned and reproduce rapidly. They live well in semideserts and in mountainous regions where there is little food for horned cattle.

Various breeds of sheep have been obtained while domesticating certain species of wild rams, namely, the mouflon and the argali. Sheep breeding today is a major branch of animal husbandry, supplying raw materials to light industry, such as: wool, sheepskin, astrakhan, and foodstuffs, such as meat, fat, and milk (the latter is used for the production of various kinds of cheese).

More than 20 breeds of pigs, adapted to the local conditions in various regions, are reared in our country, for example, the white Ukrainian, Mirgorod, Siberian, Lithuanian breeds.

Highly nutritious meat and fat, as well as leather and other products, are produced from pigs. The best breeds of pigs are characterized by high fertility (10-12 sucklings per litter), rapid growth of the young and good assimilation of food.

INDUSTRIAL ANIMAL HUSBANDRY. Modern animal husbandry is developing by building large animal breeding complexes and specialized farms that supply the population the year round with foodstuffs and industry

with raw materials. Comprehensive care of the animals is performed by means of various mechanisms that reduce manual labour to a minimum. Therefore, the farms are staffed by a small but skilled collective of workers. Most modern mechanization and automation are used at animal breeding complexes where a thousand or more heads of horned cattle or dozens of thousands of pigs are kept simultaneously. Besides the main farm, an animal breeding complex includes various undertakings (to grow and store up various fodder) and plants for the production of mixed food.

At dairy farms, the animals are kept permanently in rooms where various equipment is used to milk the animals, process the milk, distribute fodder, supply fresh water to the automatic waterers. Great attention is paid to correct and nutritious feeding of the animals. Thus, besides hay, silage, and root vegetables, the diet of dairy cows includes green and concentrated food containing mineral salts, vitamins, and other substances. When fattening pigs, mixed food is used in the form of grass meal, fish and meat waste, vitamins, and mineral additives. A veterinary service watches over the health of the animals and implements measure to prevent diseases.

? △
1. What is the value of breeds of horned cattle for man?
2. What products are obtained from small cattle?
3. Why is it profitable to rear domestic pigs?
4. How are animals cared for at animal breeding complexes?

2.74 Order: Perissodactyla

The wild horse (!) was found in the steppes and semideserts of Central Asia in the last century by Nikolai Mikhailovich Przewalski, a famous Russian traveller. It resembles a domestic horse. The firm, strong feet of a horse are adapted well to rapid running on the ground. A horse's foot has only one (third) digit. The other digits are present as vestigial structures. All perissodactyles (odd-toed ungulates) have an odd number of digits (1 or 3).

The wild horse is covered with short, yellow-gray hair, making the horse almost invisible on monotonous plains. The wild horse detects danger rapidly, owing to its sharp senses of smell and hearing, and keen vision. Wild horses can run long distances when escaping from enemies, or searching for watering-places and convenient pastures. They feed on the dry vegetation of arid steppes and semideserts. The wild horse has large incisors and molars. It cuts off plants with its incisors, holding them by means of large mobile lips. The food is ground by the flat surfaces of the molar teeth that are covered with folds of firm enamel. Horses eat abundantly and digest the food for a long time. It has a simple single-chambered stomach; the food is held for some time in the spacious caecum (blind gut) for additional processing.

DOMESTIC HORSE. Very few wild horses have survived till the present time, because they were hunted extensively for their flesh and hides, which,

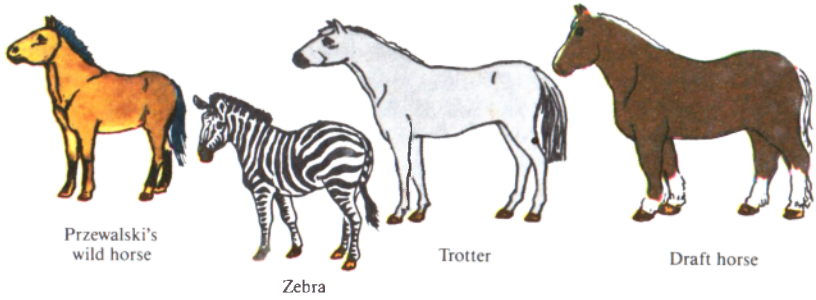


Fig. 177. Wild and domestic horses

possibly, was the reason for domesticating this animal. Many peoples in Asia today eat horse-flesh and drink koumiss, which is made of fermented mare's milk. Man started to use horses later for riding and drawing heavy loads. The Orlovsky trotter and the Don horse are domestic horses who are famous worldwide. A breed of horses has been raised in our country to draw heavy loads, the Vladimirsky draft horse. Horses of some breeds are adapted for use under local conditions. Thus, the Yakutsk horse easily endures biting frosts and feeds the year round on pastures.

Rhinoceroses also belong to odd-toed ungulates: each foot of a rhinoceros terminates with three digits that are covered with small hooves, and either one or two horns are prominent on the head. The skin of a rhinoceros is naked. Rhinoceroses occur in Africa and tropical Asia. These large beasts were hunted for their horns, which supposedly possessed medicinal properties. Rhinoceroses are very rare today and all the species are under protection.

The young of odd-toed and even-toed ungulates can stand up of their feet immediately after birth and can follow the herd in a short time.

? 1. How is a wild horse adapted to life in deserts and steppes?
2. What horse breeds do you know?
△ 3. What specific features in the structure of the limbs are characteristic of a cow, a horse, a whale, a bat, a dog? (Use Figures and Index in your answer.)

2.75 Order: Primates

The word "primate" means "first". The order of primates has been called so because it includes monkeys, the most highly organized animals.

Primates are tropical dwellers; the majority of them inhabit dense forests. All other arboreal animals use their sharp claws for climbing. Unlike the latter, primates embrace the branch with long and well-developed fingers. The thumb of the fore and hindlimbs of primates can be opposed to the

other fingers, enabling the animal to hold tight to branches and to pick up tiny objects with its fingers. Monkeys have flat nails on the fingers instead of claws. The limbs are very mobile. The animals use them not only for locomotion, but to grab food, clean and comb their hair on all parts of the body. Monkeys possess excellent hearing and keen vision. Their eyes are directed forward, instead of being at the sides of the head like in the majority of other animals. They see an object with both eyes simultaneously, owing to which they determine the distance to it quite accurately. This feature of their vision is of great significance for swinging from one branch to another. Monkeys discriminate well various shapes and colours, seeing from afar mature fruit and edible insects. They feed both on plant and animal food, but they prefer, nevertheless, juicy fruit. A newly-born primate possesses vision but it is incapable of independent locomotion. It clings tightly to the wool of its mother, who carries it wherever she goes, holding her young with a hand.

Monkeys are distinguished for the big size of their brain, whose cerebrum has many gyri, olfaction is poorly developed, and they have no tactile hairs. The fingers, as well as the naked palms and soles of the feet are their main tactile organs. Monkeys are active in the daytime. They live in herds. A strong male heads the herd, and the other male members of the herd, the females and juveniles are subordinate in the herd.

Monkeys of tropical Africa are distinguished for their nostrils, that are set wide apart (owing to which they are called platyrrhine monkeys), and their

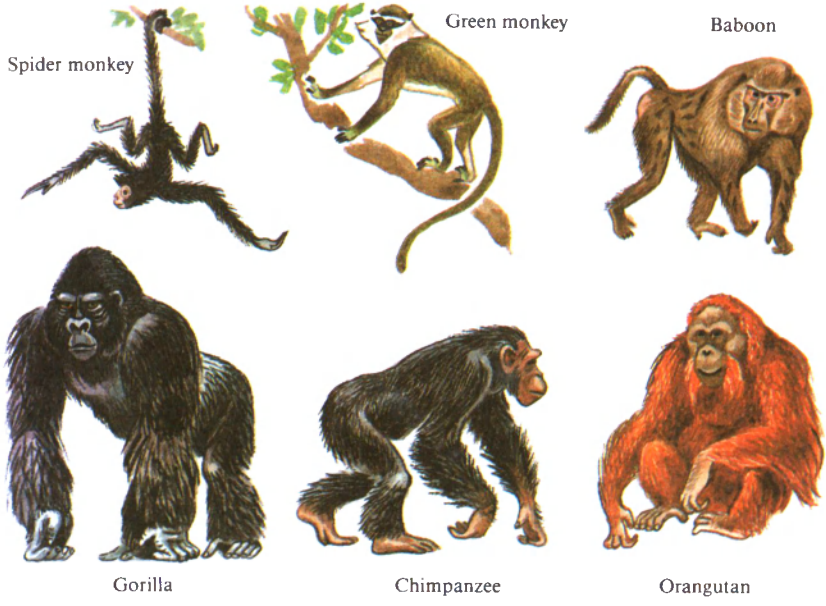


Fig. 178. Monkeys

long tail, that they use to cling to branches just as tightly as with their feet. The wooly spider monkey, who has been called so owing to its long strong limbs, is a typical representative of platyrrhine monkeys.

Catarrhine monkeys occur in Africa and tropical Asia. Their nostrils, like in man, are close together and are separated by a narrow septum. The tail of the catarrhine monkeys, like in marmosets, performs an insignificant role in climbing, while in some species it is shortened, or entirely absent. Baboons are not arboreal animals, they lead a terrestrial life and are adapted to quadrupedal knuckle walking.

Antropoid apes (!) are the largest primates, including the African gorilla, chimpanzee, and the orangutan which occurs on the Kalimantan and Sumatra Islands.

Apes spend a greater part of their time up in the trees, where they find food and build nests of boughs for the night. They are good at rapid ground locomotion on their hindlimbs, and find additional support on the backside of the hands. The animal's body assumes a half-bent position. The monkeys are tailless.

The behaviour of apes is conditioned by their highly developed brain. They possess excellent memory and quickness of wit. Conditioned reflexes develop quite easily. Experiments on chimpanzees have demonstrated that apes can apply acquired habits under the most varied conditions, which indicates the presence of rudimentary reason. Apes can make and use simple implements. Thus, a chimpanzee under natural conditions uses a bough like a lever to widen holes in the dwelling of wild bees. They break off a twig, remove the leaves and use it to extract insects and their larvae from narrow passages; they use straws as toothpicks. These animals use thick branches, stones and lumps of earth as weapons.

Chimpanzees communicate with one another by means of sounds and signs. Their facial muscles are very mobile. They express fear, animosity, pleasure, etc. Apes resemble man in this respect. It should be remembered that man also belongs to the order of primates in his structure.

1. Explain the meaning of the terms: *instinct, reflexes* (conditioned and unconditioned).
2. What specific features of structure and behaviour are common to apes and man?

2.76 Significance of Mammals and Protection of Useful Animals

The role of mammals in nature depends primarily on their number. The majority of large animals occur today quite rarely, therefore they don't render a great effect on natural communities. On the contrary, mammals of average and especially of small size are so numerous, that they play a significant role in nature. Rodents are of major

significance in this respect, on the one hand, consuming many plants and their seeds, and, on the other, serving as the principal source of food for some predators.

The significance of mammals for man is quite diverse. Many rodents are undoubtedly harmful, because they cause damage to cultivated crops and destroy food reserves. These animals are bacilli-carriers and carriers (directly or via blood-sucking arthropods) of some diseases that are dangerous for man. Predatory mammals who attack domestic cattle cause certain harm to the human economy.

The usefulness of wild mammals consists in the production of valuable fur, leather, and meat, and also fat from marine mammals.

The principal fur-bearing animals in the USSR are the squirrel, sable, muskrat, red fox, polar fox, mole. The elk, wild northern deer, boar, and some other odd-toed ungulates are hunted for their meat and hides. The hare is the main game hunted for sport.

The notion "fauna" is often used when studying animal life. *Fauna* means all the animals of an area or region.

FUR-BREEDING. The sable, silvery-black fox, mink, and other fur-bearing animals are reared at animal farms. Fur-farming is a profitable branch of the economy. Zootechnicians raise fur-bearing animals with various colours of fur. White, black, silvery-blue, and pearly minks have been raised. Modern state animal farms are large fur "factories". They are equipped with various mechanisms to facilitate the caring for the animals.

PROTECTION OF ANIMALS. Various measures for introducing useful animals from other regions or countries and helping them to acclimate are carried out in our country to enrich the fauna. In the chapter on rodents we mentioned the acclimatization of the muskrat in the USSR. The American mink was also brought from North America to the USSR. It acclimatized well and today it is hunted. Some other valuable mammals have also been acclimatized.

Many species of mammals, especially large-sized and valuable ones, started to die out by the beginning of the 20th century owing to the growth of cities and settlements, the expansion of ploughland area, and as a result of barbarous hunting.

Fig. 179. Muskrat and its house

North American buffaloes (!) and European bisons (!) have disappeared almost completely, the number of apes has reduced greatly, rhinoceroses and some species of cetaceans are threatened with extinction. The number of many large representatives of cats has reduced drastically. Laws on environmental protection have been adopted currently in many countries.

Many species of mammals are protected in the USSR by law, and their hunting is prohibited totally. Fur-bearing animals are hunted in strict conformity with rules, which establish the hunting season and the number of animals which may be killed. An increasing number of amateur hunters go to the forests now with photo and movie-cameras instead of guns.

?

1. What is the benefit of wild mammals for man?
2. Name the species of domestic animals you know. Name their position in the system (phylum, class, order).

△

3. What rare animals do you know that are protected by law? (Use the parts of the textbook with the sign (!) in your answer.)

3 The Role of Animals in Nature and Their Protection

3.1 Natural Communities of Plants and Animals

INTERRELATIONSHIP BETWEEN ANIMALS AND PLANTS IN NATURAL COMMUNITIES. Studying botany, you learned that plants form natural groups, or communities, under natural conditions. A combination of certain plant species is characteristic of each plant community. Animals are also members of these communities, because they feed on plants (plant-eating animals), find shelter in vegetation, often serve as pollinators, or are associated with plants in some other way. Therefore, each species of animals does not occur everywhere within its geographic range, but only in certain communities of plants and other animal species.

A *natural community* is the totality of plants, animals, microorganisms which are adapted to the conditions of life on a certain territory and affect both one another and the factors of inanimate nature. Each natural community is characterized by various relationships: food, habitat, etc. Food links are called *nutrition chains.*

Frogs live in shady humid places, usually near water bodies; lizards prefer arid habitats. Both frogs and lizards feed on insects, but their diets are different. Frogs eat mosquitoes, midges, and other insects who live in shady humid places. A lizard hunts grasshoppers and their larvae, small beetles, and other insects in arid habitats that are warmed well by the sun. The vegetation in the habitats of a frog and a lizard is also different (i.e. the plant communities are different). Frogs live in areas with an abundance of rich grass, shrubs, where willows, alder and aspen trees grow. Lizards occur on sandy and stony ground, in heaths and pine forests.

A MEADOW–A NATURAL BIOCENOSIS. Imagine a meadow at the beginning of summer. It is covered with a blanket of young green grass and bright blossoming flowers. An abundance of insects swarm over the meadow at this time of year. Bees and bumble-bees are digging busily in the flowers, collecting nectar and pollen to feed themselves and their larvae. The larvae of butterflies feed on the green parts of meadow grass. Butterflies flutter all around. They suck flower nectar and deposit eggs on plants that the larvae will feed on later.

1 – Bumble-bee; *2* – Dollal bird with a dragon fly in its beak; *3* – Eagle owl; *4* – Squirrel; *5* – Hollow for birds; *6* – Spider

Many birds that are typical of a meadow (for example, the skylark) feed on the seeds of herbacious vegetation and on insects. Thus, the life of a skylark depends on the availability of animal and vegetative food.

Examples of nutrition chains are shown in Figure 180 for a meadow natural community. Worms feed on the dead parts of plants. The parts of the plants above the ground's surface are consumed by the larvae of butterflies, grasshoppers, etc. Insectivorous birds, for example, skylarks, feed on these insects.

Thus, each nutrition chain begins with plants that create organic substances out of inorganic ones. Animals feed on plants and make up the link of consumers. The chain ends with the link consisting of bacteria, moulds. These organisms transform organic substances into mineral ones. The mineral substances can be used again by the plants.

Small dead animals and birds are buried in the soil and are consumed later by burying beetles. Organic substances are added to the soil as a result of their vital activity. Hence, a natural community consists of three inseparably interrelated parts: plants, animals, and elements of inanimate nature.

Now the close relationship between all the members of the community becomes clear even if they have no direct contacts with one another. All the members of a community are interdependent under natural conditions and are in natural equilibrium. If the number of insects reduces for some reason, insectivorous birds will not have enough food. They will be unable to feed all

Fig. 180. Inhabitants of a meadow biocenosis

Fig. 181. European bison

their young and some of the latter will perish. The insects will then have fewer enemies and they will reproduce again. Then the number of birds will increase and they will start to exterminate the insects. If one of the members of a community is removed artificially, it will inevitably affect all the others. When a nest of bumble-bees is destroyed in a meadow, the plants that are pollinated by them stop producing seeds, the amount of grass reduces, insects feeding on the grass and birds will disappear. The grass will thin out, begin to wither, and there will be fewer earthworms in the soil, many meadow plants and animals will disappear, and others will appear instead of them, i.e. the entire character of the community will change.

As you see, plants, animals, and microorganisms are closely interrelated in a natural community. These relations ensure the matter cycle and equilibrium in nature.

? △

1. Recall the notion of a plant community in the textbook *Botany*.
2. Name the main links in the nutrition chain of a meadow natural community.
3. Use Figure 180 to talk about the food interrelationship of animals in a meadow community.

3.2 Effect of Man on Natural Communities

NATURAL COMMUNITIES AND MAN. Men fought with various natural forces during the early stages of evolution of human society: they cleared plots to sow crops, defended themselves from predators. The influence of man on nature at that time was insignificant and did not cause noticeable changes in the communities owing to the primitive character of their weapons and implements of labour, and the small size of the human population. The influence of man on nature grew greatly along with the increase of the population on Earth, improvement of hunting weapons, agricultural implements and fishing means. This influence intensified many times during the last few decades: mechanization of agriculture, growth of industrial enterprises and cities, construction of roads and hydraulic works changed radically the appearance of the Earth. Man continues to encroach upon nature and only a few virginal natural communities have been preserved.

REDUCTION OF ANIMAL POPULATION. Violation of natural communities is not always justified by necessity. The number of wild animals reduces frequently as a result of barbarous extermination. Only one hundred years ago strong herds of millions of buffaloes, wild oxen (related to bisons) grazed in the steppes of North America. Unlimited hunting of these large herbivorous animals reduced their number in 20 years to almost one thousand head. The American passenger pigeon was fully exterminated in a very short time, while flocks of these birds once numbered billions of individuals! We spoke earlier about the reduction of the populations of other valuable animals. Some of them were exterminated as a result of poor knowledge of their biology. Thus, the pouched wolf, a very rare marsupial, occurred only 50 years ago in Tasmania. The pouched wolf fed on local wild animals (kangaroos, echidnas) and did not create any danger for sheep breeding. However, the sheep-breeders declared merciless war on the pouched wolf because of its external resemblance to the European predator. The last pouched wolf was killed in 1933. By the way, even a true wolf is a useful member of the community under certain conditions. Wolves prey primarily on sick and weak animals, thereby preventing the spreading of diseases. The herds of wild herbivorous animals reduced drastically owing to infectious diseases in regions where wolves were exterminated fully. Certainly, this doesn't mean that it is necessary to increase the number of wolves. If the number of these predators is great, they cause damage to valuable wild animals and attack domestic cattle.

■ Give examples of man's influence on natural communities.

3.3 Protection of the Animal World

LAWS ON ENVIRONMENTAL PROTECTION. The economic activities of man expanded to such a degree by the beginning of the 20th century that it began to render a substantial negative effect on nature. Scientists were the first to notice this. A permanent environmental protection commission was set up at the Russian Geographical Society in 1914 on the initiative of Academician I. P. Borodin. Scientific and social organizations of this kind were set up also in some other countries. They united in 1948 into the International Union for the Conservation of Nature and Natural Resources (IUCN).

According to an IUCN project, scientists collected data worldwide on species of plants and animals that were threatened with extinction so as to be able to take measures to preserve them. Lists of these species with data on their biology, habitats, and number are published by IUCN in a special book called the *Red Book*. A *Red Book of the USSR* has been published in our country, listing animals and plants that are rare or on the verge of extinction, therefore demanding special preservation.

A scientific survey of the current state of nature has served as the bases for adopting laws in some countries for the preservation of all the main component parts of the environment.

The role of schoolchildren in environmental protection, including protection of the animal world, is significant. It is not restricted to knowing merely that one should neither destroy bird's nests and anthills, nor kill bumble-bees, and other useful insects. It is not enough to make and hang up several houses for birds. Knowledge of the school course of zoology will help each one of you to behave correctly and reasonably in relation to nature.

One should be very careful with fire. If one makes a fire improperly, it may be the cause of the terrible forest fire, and not only will trees burn down, but all the animals in the forest will perish also.

One should neither sing, shout, nor play musical instruments in nature. Noise frightens small birds, they leave their nests and their eggs and nestlings may become the prey of predators. A forest, a field, a steppe has its own natural music: the singing of birds, chirring of insects. Listen to this music.

One of the main rules to be observed when going to the country is to maintain cleanliness, which should be a mandatory quality of any intelligent person. One should not throw away pieces of paper, empty cans and jars, plastic bags, and other waste. All these objects contaminate the environment, make it unfit for human recreation, and for the animal life. Broken glass is most dangerous, because it remains forever and people and animals may be injured badly.

1. What species of animals are listed in the *Red Book*?
2. What are the basic provisions of the Law on the Preservation and Use of the Animal World?
3. What is the role of schoolchildren in environmental preservation?

4. Name the species of animals preserved in the USSR (use the material of the textbook).

4 Evolution of the Animal World

4.1 Origin of Species of Modern Animals

INCONSISTENCY OF VIEWS ON INVARIABILITY OF ANIMAL SPECIES. It was assumed in ancient times and in the Middle Ages that nature was invariable, and all the contemporary animals and plants were always the same. However, by the beginning of the 19th century, facts were revealed indicating that the Earth was populated in ancient times with other animals that were unlike or resembled modern ones only slightly. Fossils of these animals in the form of traces and bones were discovered in excavations. Adherents of religion considered that extinct animals were unsuccessful creations of god. They said that instead of the latter he created modern animals, who have remained invariable since that time. Certainly, real scientists could not be satisfied with these "explanations". Some zoologists, including the well-known French scientist Lamarck, proved that modern animals were descendents of extinct animals, who changed continuously under the influence of environmental conditions. However, no one could explain convincingly how these changes influenced the animals, causing them to change. Charles Darwin, the great English naturalist, solved this mystery of nature.

DIFFERENCES BETWEEN ANIMALS OF ONE SPECIES. VARIATION. Darwin suggested that though animals of one species are very much alike, they are not identical. This is easy to see.

Certainly, you have all seen flocks of blue rock pigeons many times and noticed that the plumage was not the same in all the birds. The majority of birds have a uniform bluish colour with a beautiful metallic tint, but some birds have white feathers on their wings. Sometimes the birds are speckled. The differences in the coloration of plumage are best seen when the flock takes off. Then you see the underside of the wings: bluish, light-gray, or white. Pigeons differ also by other features: size and colour of the bill, length of the feet, number of scales on the feet, tail length, etc. Darwin called the differences between individuals of one species *variation*. Variation is characteristic of all species of animals and plants. Darwin believed that the cause of organism variation was the influence of new living conditions as compared to the conditions under which their ancestors existed. Variation in

— Exhibits of the Paleontological Museum of the USSR Academy of Sciences (Moscow)

wild blue rock pigeons, occurring in the rocky regions of Western Europe, is insignificant, because the natural conditions change very slowly. But, variation is significant in semi-domesticated blue rock pigeons, belonging to the same species, because man continuously changes the conditions of the environment within which the semi-domesticated pigeons live.

INHERITANCE. Darwin noticed that all innate characteristics pass on from one generation to another. The capability of organisms to pass innate characteristics to their progeny is called *inheritance*. If new characteristics are not innate, but have been acquired during the life of an organism, they are not inherited. It is known that the tail is cut off from dogs of certain breeds, for example, fox-terriers, from generation to generation. However, this new external characteristic (a short tail) is not inherited. All the offspring of fox-terriers are born with tails of normal length.

RAISING BREEDS OF DOMESTIC ANIMALS. ARTIFICIAL SELECTION. Man has raised numerous breeds of domestic animals: small and large horned cattle, horses, dogs, rabbits, chickens, ducks, pigeons. Many fish species have been bred, including both pond and aquarium breeds. There are various breeds of silkworms and honeybees. How did these breeds appear?

When man noticed in one of its domestic animals certain especially useful characteristics, the animal was isolated, or, as Darwin said, it was selected, its offspring were preserved if they inherited the same beneficial traits.

Thus, selecting domestic dogs with long legs who ran the fastest, a breed of Russian wolfhounds was raised, and a dachshund was bred by selecting dogs with short legs. When it is necessary to raise a dairy breed of cattle, the

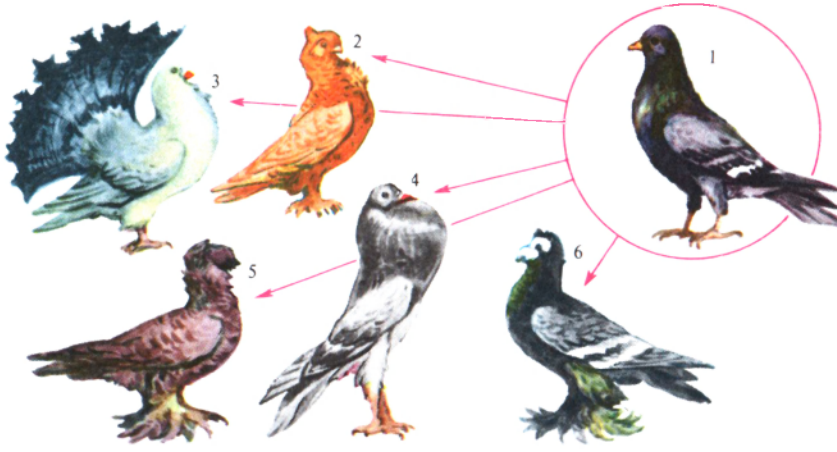


Fig. 182. Example of artificial selection: *1* – Wild blue rock-dove pigeon, ancestor of the most varied breeds of pigeons; breeds: *2* – Jacobinic; *3* – Peacock; *4* – Pouter pigeon; *5* – Owl; *6* – Tumble pigeon

animals are selected according to high milk yield characteristics and no attention is paid to the body weight. When raising meat breeds, the largest animals are selected even if they yield little milk. Darwin called this *artificial* selection, because it is done by man.

STRUGGLE FOR EXISTENCE AND NATURAL SELECTION. People take care of their domestic animals: feed and provide them with shelter, cure them and protect them from predatory animals. Wild animals have to struggle for their existence alone. This doesn't imply at all that it is necessary to struggle with the aid of teeth and claws. It is not the method of struggle that is important, but its result. The one who survives is the winner. Thus, many birds perish in severe winters from low temperatures and food shortages. They all struggle for life by looking for food. The more adroit ones get more food, because they are the first to notice and grab it. The other birds perish. Only those animals who are better adapted to the environment survive in the struggle for existence, while less adapted ones perish. This means that selection takes place, which is not artificial but *natural* selection, i.e. it occurs in nature unassisted by man.

The species change continuously as a result of natural selection and become better adapted to the environment.

ORIGINATION OF NEW SPECIES. Man, using artificial selection, raises new breeds of domestic animals and cultivated plants. New species originate in nature in the same way under the influence of natural selection.

Before Darwin, all the attempts to prove the variation of species and explain its reasons were a failure. Darwin proved that evolution is continuous from lower forms to higher ones in the world of plants and animals.

The book of this great scientist *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* was a real revolution in science.

? △

1. Is it possible to consider the differences between a chicken and a rooster, a lion and a lioness, ant workers and ant soldiers as variation?
2. Why are unconditioned reflexes inherited, and conditioned ones not passed on?
3. What is the difference between artificial and natural selection? Give several examples.

4.2 Evidence of the Animal World Evolution

PALEONTOLOGICAL DATA. The historical development of the animal world from lower to higher forms, i.e. its evolution, has continued for more than a thousand million years. Man, who appeared only about a million years ago, could not witness the origination and development of modern animal groups: they all appeared long before man. Hence, it is possible to make suppositions about the course of

evolution only by studying modern animals and fossil remains of extinct organisms. The science of extinct organisms is called *paleontology*.

Scientists discover whole specimens of extinct animals very rarely. A well-preserved mammoth was found in a layer of permafrost in Northern Siberia, as were remains of extinct rodents and other small animals. More often only bones of vertebrate animals are found in fossil remains, along with the solid parts of invertebrates, for example, shells, spines. Sometimes only traces and fossils are preserved.

It is possible to judge of the antiquity of the fossil remains by the depth of their occurrence: traces and fossils of ancient organisms are found at great depths, and the remains of recently dying organisms are closer to the surface. Paleontologists can reconstruct the appearance of an animal by their traces, fossils, and even individual bones.

The imprint left by the archaeopteryx enabled scientists to reconstruct the history of the origin of birds. Numerous fossil remains of long extinct arthropods, trilobites, serve as important proof of the origin of arthropods from annelids. Trilobites occupy an intermediate position in terms of their structure between animals of these two phyla.

Many fossil remains are available of animals who died out not very long ago, but data on the appearance of the most ancient organisms are fragmentary.

COMPARATIVE ANATOMICAL DATA. *Comparative anatomy*, which implies a comparison of the structure of various modern animals, comes to the aid in this case. For example, coelenterates have stinging cells (see Figure 17). It is possible to assume on this basis that the ancestors of modern coelenterates were unicellular organisms at one time and roughly resembled modern flagellate protozoa.

It has been mentioned earlier that there is a great resemblance between the structure of arthropods and marine annelids. Thus, the origin of arthropods from annelids is proved not only by paleontological research, but also by comparative-anatomical data.

EMBRIOLOGICAL DATA. In some cases, when the study of the structure of adult animals is insufficient, it is possible to discover traits of similarities by comparing larvae of various groups of animals, or by studying their embryonic development. The presence of gill slits in the embryos of terrestrial vertebrates indisputably proves their origin from fishlike ancestors, who lived in water.

Thus, the science of the individual development of animals from an egg, *embriology*, is also of significance in retracting the historical course of animal evolution.

Data of paleontology, comparative anatomy, and embriology serve as a proof of the evolutionary development of the animal world and enable us to trace individual stages of this complex and longterm process.

? 1. The fossil remains of what extinct animals have made it possible to determine the origin of mammals?

△ 2. What comparative-anatomical data can you present to prove the origin of reptiles from amphibia?
3. What embriological data confirm the origin of amphibia from fish?

4.3 Brief Essay on the Main Stages of Animal Evolution

ORIGIN OF LIFE. The first living organisms originated in the sea and looked like tiny mucous lumps, consisting of a protein substance. They had neither nuclei, nor vacuoles, nor other formed parts of cells, but they could grow, assimilating nutrients from the environment, and reproduce. These primitive organisms gradually became more complicated during the process of natural selection, and later the first unicellular organisms originated from them. Differences in the methods of feeding caused the origination of primitive animals and plants at the early stages of development of the organic world.

DIAGRAM OF EVOLUTIONARY DEVELOPMENT. To understand better the relationship between the groups of organisms, it is possible to imagine their development in the form of a unified diagram (see inside front cover of the book). Plants separated from animals at the earliest stages of development. But the separation did not occur all at once. First, organisms originated that had features of both plants and animals.

Even today some protozoa (for example, the euglena) are capable of photosynthesis in addition to feeding on ready organic substances. The majority of scientists consider ancient unicellular organisms, flagellates, to be the ancestors of primitive plants and animals.

PROTOZOA – THE LOWEST MODERN ANIMALS. Protozoa, unicellular animals of the most simple structure, are placed at the bottom of the diagram. It can be supposed that primitive protozoa greatly resembled modern ones. This is confirmed by comparing the skeletons of long extinct fossils and modern rhizopoda. Some shell marine rhizopods living some 400 million years ago exist even today (see Figure 10).

ORIGIN OF MULTICELLULAR ANIMALS. Multicellular animals differ from unicellular ones primarily by the fact that their body consists of a large number of cells. However, the individual cells of multicellular organisms sometimes resemble some unicellular organisms. The internal layer of coelenterate body contains flagellar cells that are like flagellated unicellular organisms, and cells with pseudopods that are similar to amoebas. There is always an unicellular stage, the egg, in the development of each multicellular animal. All this indicates the origination of multicellular animals from unicellular ones. It is necessary to recollect here the structure of a volvox.

It is impossible to say that a volvox is a true multicellular organism, though it consists of a large number of cells. As is known, flagellate protozoa, who make up a volvox colony, are identical, while the cells in a multicellular organism are specialized and form tissues. But, owing to its

colonial structure, a volvox differs from the majority of unicellular organisms and approaches a multicellular one.

Certainly, it is impossible to consider a volvox proper as an ancestor of multicellular animals. But, probably, their ancestors were nevertheless colonial protozoa.

Coelenterates have the most simple structure of all multicellular organisms. They have no tissues, their gametes resemble unicellular organisms. Therefore, it is assumed that they originate from ancient colonial protozoa.

ORIGIN OF PLATYHELMINTHES (FLATWORMS). Flatworms, that are united into a special phylum of animals, are characterized by the most simple structure among bilateral-symmetrical animals.

The structure of the digestive system in flatworms and coelenterates is basically similar. In both it has the form of a blind closed sac with a single opening – a mouth. Coelenterates are characterized by radial symmetry of the body, which corresponds well to the sedentary mode of life of these animals. It is possible that flatworms originated from now extinct mobile coelenterates. In connection with their crawling the anterior and posterior ends, as well as the ventral and dorsal sides developed in these animals. They became bilateral-symmetrical. Turbellarian worms were the first to appear, and flukes and tapeworms appeared later.

ORIGIN OF ROUNDWORMS. The main feature distinguishing roundworms is the presence of a body cavity. It is believed that roundworms originated from flatworms as a result of the formation of this cavity. An anal opening formed in the roundworms and the food moved through the digestive system in one direction.

ORIGIN OF ANNELIDS. The division of the body into segments, which led to the origin on annelids, is a significant moment in the evolution of animals. A circulatory system, which also developed first in annelids, is present in all phyla of animals of higher organization. Undoubtedly, ancient marine polychaete annelids were ancestors of oligochaete annelids, arthropods, and mollusks.

ORIGIN OF ARTHROPODS. Ancient arthropod animals, trilobites, resembled marine polychaete annelids, but unlike the latter, they had a pair of limbs on each segment of the body that were like the feet of arthropods. They occupied an intermediate position between modern arthropods and ancient annelids. Numerous comparative-anatomical data point to the origin of arthropods from annelids. As discussed earlier (see Sec. 2.29), crustacea, arachnids and insects originated independently of one another.

ORIGIN OF MOLLUSKS. Mollusks are unlike annelids externally and in terms of their internal structure. However, the early stages of the egg's development is identical to that in annelids. Many species of marine gastropods have larvae that greatly resemble the larvae of marine polychaete worms. Thus, the origin of mollusks from annelids is proved by embryological research.

ORIGIN OF VERTEBRATES. Research on the development of an egg of lower chordate animals (for example, a lancelet) points to the considerable

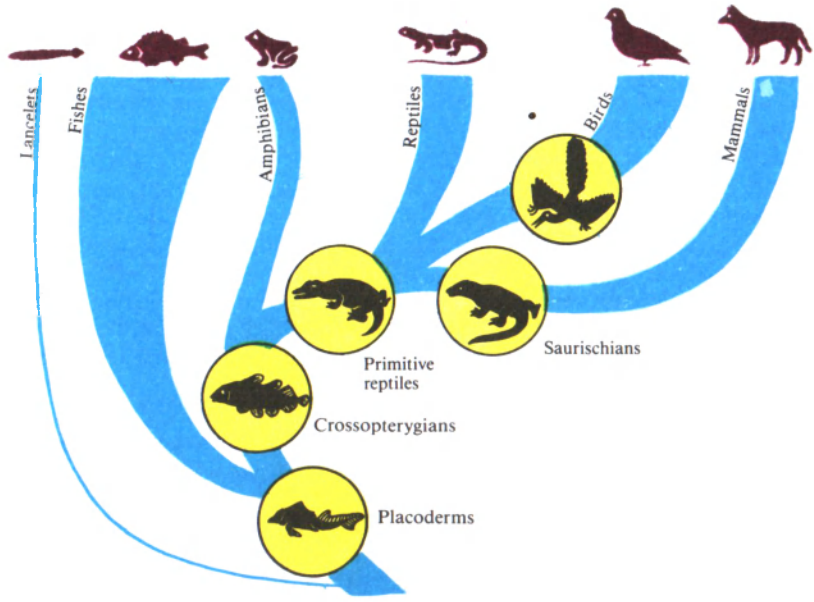


Fig. 183. Evolutionary diagram of chordate classes

differences between chordates and the majority of other phyla of animals. At the same time, a lancelet resembles annelids and mollusks in the structure of the circulatory system and method of feeding. Thus, this animal occupies an intermediate position between invertebrates and vertebrates.

It is comparatively easy to reconstruct the succession of historical development of vertebrates, because many fossil remains have been preserved.

Animals with paired fins appeared among ancient chordates. They were adroit predators. Sharp teeth developed in these animals owing to their predatory mode of life. They made quick and complex movements when looking for and pursuing prey. Their sense organs and the central nervous

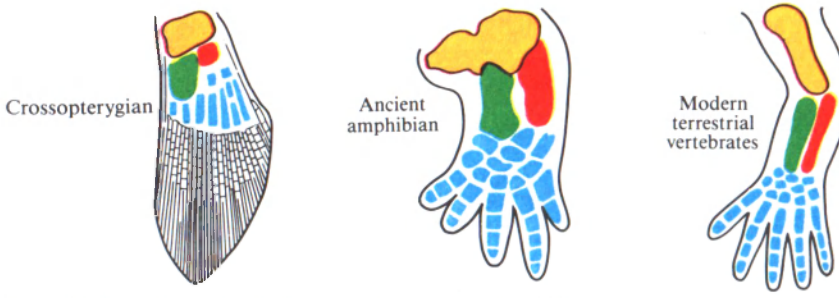


Fig. 184. Development of skeleton in paired limbs. Diagram

system developed greatly as a result of natural selection. Thus, the first fish originated that externally resembled modern sharks.

The origin of amphibia is associated with two significant factors: the transformation of paired fins into terrestrial limbs, and the development of pulmonary respiration and two circles of blood circulation. These new specific features of amphibia, distinguishing them from fish, appeared as a result of adaptation to terrestrial mode of life.

Subsequent adaptation of amphibia to terrestrial life (loss of dermal respiration, internal fertilization, laying eggs on land and not in water) led to the origin of the first reptiles.

These animals were very numerous and diverse during the prime period of development of this class, but the majority of reptiles died out, being unable to withstand competition with the warm-blooded animals which had begun to appear: mammals and birds.

The main specific feature of birds and mammals is their warm-bloodedness. Owing to their constant body temperature, mammals and birds can live under the most diverse, and even severe conditions, where amphibia and reptiles cannot exist.

Another important specific feature of birds and mammals is their care of progeny, ensuring preservation of the number in the species.

THE RELATIONSHIP BETWEEN MAN AND ANIMALS. The structure of a human body is the same as in all vertebrates in its general features. Mammals are most like man. It was believed for a long time that the resemblance was accidental. According to religious teachings, there could be no relationship between man and animals.

On the basis of many facts, Charles Darwin proved in his book *Origin of Man* that man was not created by god, but appeared as a result of the evolutionary development of mammals. Science has been enriched since that time by many other evidences of the origin of man from animals.

It is impossible to say that a man is an animal, but man is closely associated by origin with the animal world. You will see this more than once when you study later the structure and vital activity of the human body.

Thus, the long development of the organic world on Earth led to the appearance of man. Possessing reason and the capacity to work, man subjugated living and inanimate nature. The relations between men and the development of human society are subordinated not to biological, but to social laws, which you will study in courses on history and social science.

?

1. On the basis of what facts can it be maintained that multicellular animals originated from unicellular ones?

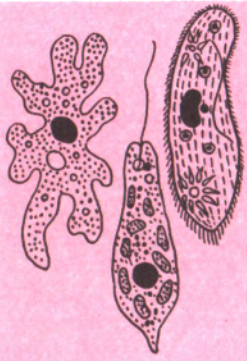
△

2. Examine by means of the Index (according to the pages stated therein) how the term "egg" is used in the textbook when describing various groups of animals (from lower to higher). What conclusion can be drawn?
3. What dependence exists between the mode of life of an animal and the symmetry of its body?
4. What does the origin of amphibia from aquatic animals prove?
5. What advantages does warm-bloodedness give birds and mammals in their struggle for life?

Before studying the brief characteristics of the main groups of animals, examine the inside front cover of the book. The diagram of the animal world's evolution presents the same symbolic images of representatives of each group as are given in the Appendix. By comparing these images and reading the characteristics of the phyla and some classes of animal, you will understand better the process of evolution in nature from lower, simple forms to higher, more complicated ones.

Appendix

Brief Characteristics of Main Phyla and Classes of Animals



Phylum: Protozoa

The body of a protozoa is microscopically small and consists of one cell, but this cell is an integral organism, leading an independent existence. Some species of protozoa form colonies. Protozoa occur in fresh-water bodies, seas, and in the soil. Some protozoa parasitize other organisms. The phylum includes more than 30 000 species.

Phylum: Coelenterata

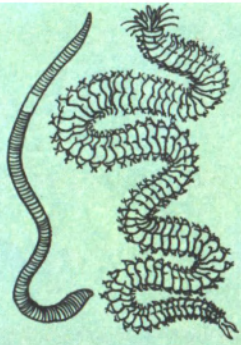
Coelenterates are lower multicellular animals, whose body consists of two layers of cells and has radial symmetry. Coelenterates are characterized by the presence of stinging cells. All coelenterates are aquatic, mainly marine animals. About 8000 species are known.

Phylum: Platyhelminths (Flatworms)

The body of flatworms and other animals of higher organized phyla consists of three layers of cells. The digestive cavity, like in coelenterates, opens externally via one opening, the mouth; some flatworms, having no intestine, absorb food through the entire body surface. Flatworms occur in both fresh and salt water, they also live in the soil in tropical countries with a humid climate. Many parasites of man and animals are known among flatworms. More than 16 000 species are known in this phylum.

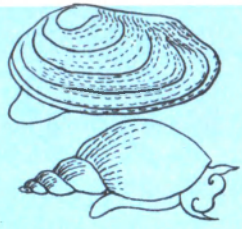
Phylum: Nematoda (Roundworms)

Roundworms have an elongated body round in cross section. Unlike flatworms, the body of a roundworm contains a cavity in which all the internal organs are located. Representatives of this phylum occur in water and in the soil. Many of them are parasites of plants, animals, and man. More than 23 000 species of roundworms are known.



Phylum: Annelida

The body of annelids consists of a large number of segments, each of which has setae on the lateral sides that play an important role in the locomotion of the animal. Like in roundworms, the internal organs of annelids are located in the body cavity (coelom), but the structure of annelids is more complex. They have a circulatory system. Large accumulations of nerve cells are in the anterior part of the body: the subpharyngeal and suprapharyngeal ganglia. Annelids inhabit both fresh and salt water, and the soil. About 17 000 species of annelids are known.



Phylum: Mollusca

The appearance of mollusks differs from annelids but they are undoubtedly related to the latter. This is confirmed by the great resemblance between the structure of the larvae of marine clamworms (polychaete) and some marine gastropod mollusks. Mollusks live in both fresh and salt water, and on land.

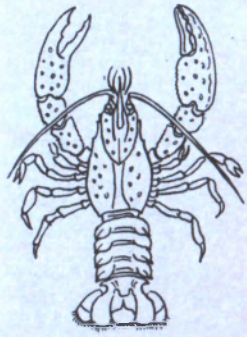
The body of a gastropod mollusk is divided into a head, a trunk, and a foot. As a rule, it is covered with a shell, secreted by a skin fold, a mantle.

Bivalve mollusks lead a sedentary, or an attached, mode of life, the head is not developed. About 130 000 species of this phylum are known.

Phylum: Arthropoda

Arthropods are distinguished by a solid covering, consisting of a special organic substance called chitin. The chitinous cuticle is light but very strong, therefore it serves also as the exoskeleton.

Like that of annelids, the body of arthropods consists of segments, but their structures are dissimilar. These segments join into several parts of the body that are quite different from one another. Most often it is the head, thorax, and abdomen. The segmented limbs are one of the main features of arthropods. The chitinous covering is not elastic. Therefore, the growth of arthropods is not steady. Shedding occurs periodically and the old cuticle is replaced by a new one. Arthropods outnumber all other groups of animals taken together in terms of their quantity and diversity of species. There are more than 1 000 000 species.

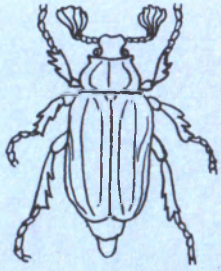


Class: Crustacea

Crustacea are mainly aquatic arthropods. They breathe oxygen dissolved in the water, by means of gills. The body of crustacea is divided into a cephalothorax and an abdomen. Both these parts consist of fused or jointed segments, each of which has a pair of limbs – antennae, mouthparts, and legs. Crustacea occur in fresh and salt water. Some of them have adapted to terrestrial life, but even in this case they breathe by means of gills. About 25 000 species are known.

Class: Arachnida

Arachnids are terrestrial arthropods, who breathe by means of tracheae and lungs. The body of arachnids, like in crustacea, is divided into a cephalothorax and an abdomen, but the mouthparts and legs are located in arachnids only on the cephalothorax. They have no antennae. Many arachnids are parasites. About 35 000 species are included in this class.



Class: Insecta

The body of an insect consists of a head with mouthparts and antennae, a thorax with three pairs of legs and wings, and an abdomen. The majority of insects can fly. They breathe atmospheric air by means of a branching system of tracheae. Insects pass through two or three stages of development. It is the most numerous class, including the majority of species (about a million) of the phylum Arthropoda.

Phylum: Chordata

Chordates are distinguished by the presence of an elastic supporting – a notochord, laying over the intestine. The majority of Chordates possess the notochord only in embrionic stages. The digestive system is represented by an intestine, that passes through the body (beginning with the mouth and ending with the anus), and by the well-developed digestive glands. The pharynx of Chordates, during the whole life of the animal, or in embryo only, is perforated with gill slits. The central nervous system, situated dorsally, is tubular, the brain is well-developed.

So three characteristics sets the chordates apart from all other animals – being the possession of a notochord, pharyngeal gill slits and a tubular nervous system dorsally situated in the body.

Class: Pisces (Fishes)

Fish are aquatic chordates. Paired limbs form fins. Fish breathe by means of gills. The circulatory system is a closed circle, the heart is two-chambered. About 20 000 species are known.

Class: Amphibia

Amphibia are semi-aquatic, semi-terrestrial chordates. Their limbs consist of three jointed parts that end with digits. They breathe atmospheric air with their lungs and through their moist skin. They have two circulatory circles, a three-chambered heart. The larva has gills and lives in water. About 3000 species are known.

Class: Reptilia

Reptiles are terrestrial chordate animals. They breathe by means of lungs, their skin is dry. They have two circulatory circles, a three-chambered heart, wherein the ventricles contain an incomplete internal septum, separating arterial blood from venous. About 6000 species are known.

Class: Aves (Birds)

Birds are warm-blooded chordates. Their heart is four-chambered. The skin contains no glands, the body is covered with horny feathers. The jaws are toothless. Birds represent the only class of chordate animals that have developed fully under the effect of adaptation to flight. The forelimbs of birds are modified into wings. More than 8500 species are known.

Class: Mammalia, or Beasts

These are warm-blooded chordate animals. The heart is four-chambered. The skin contains a large number of glands. A hair covering is developed. They nurse their young with milk, which is produced in the mammary glands of the female. The central nervous system is highly developed. Mammals inhabit land, fresh and salt water. They all evolved from terrestrial ancestors. More than 4000 species are known.

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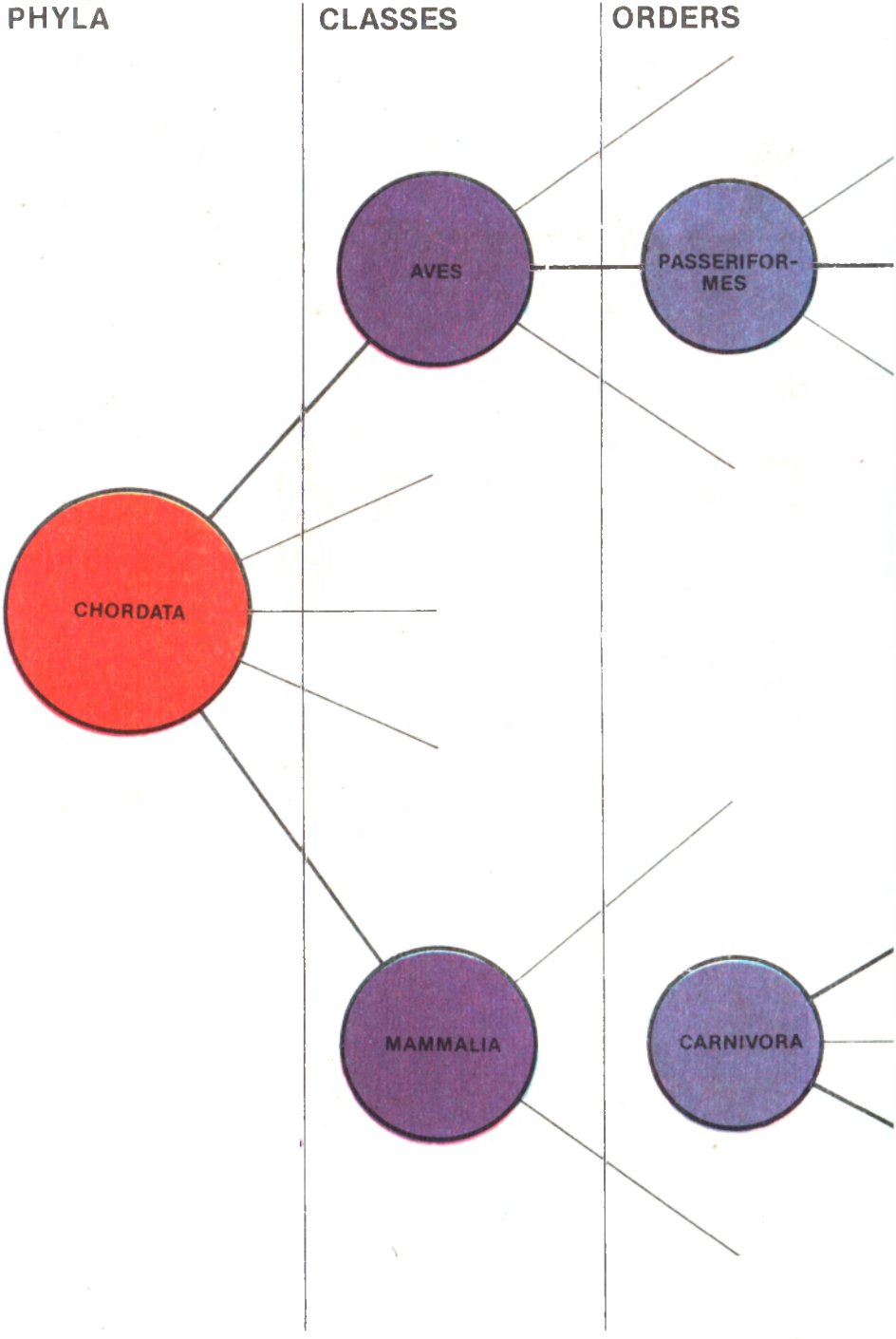
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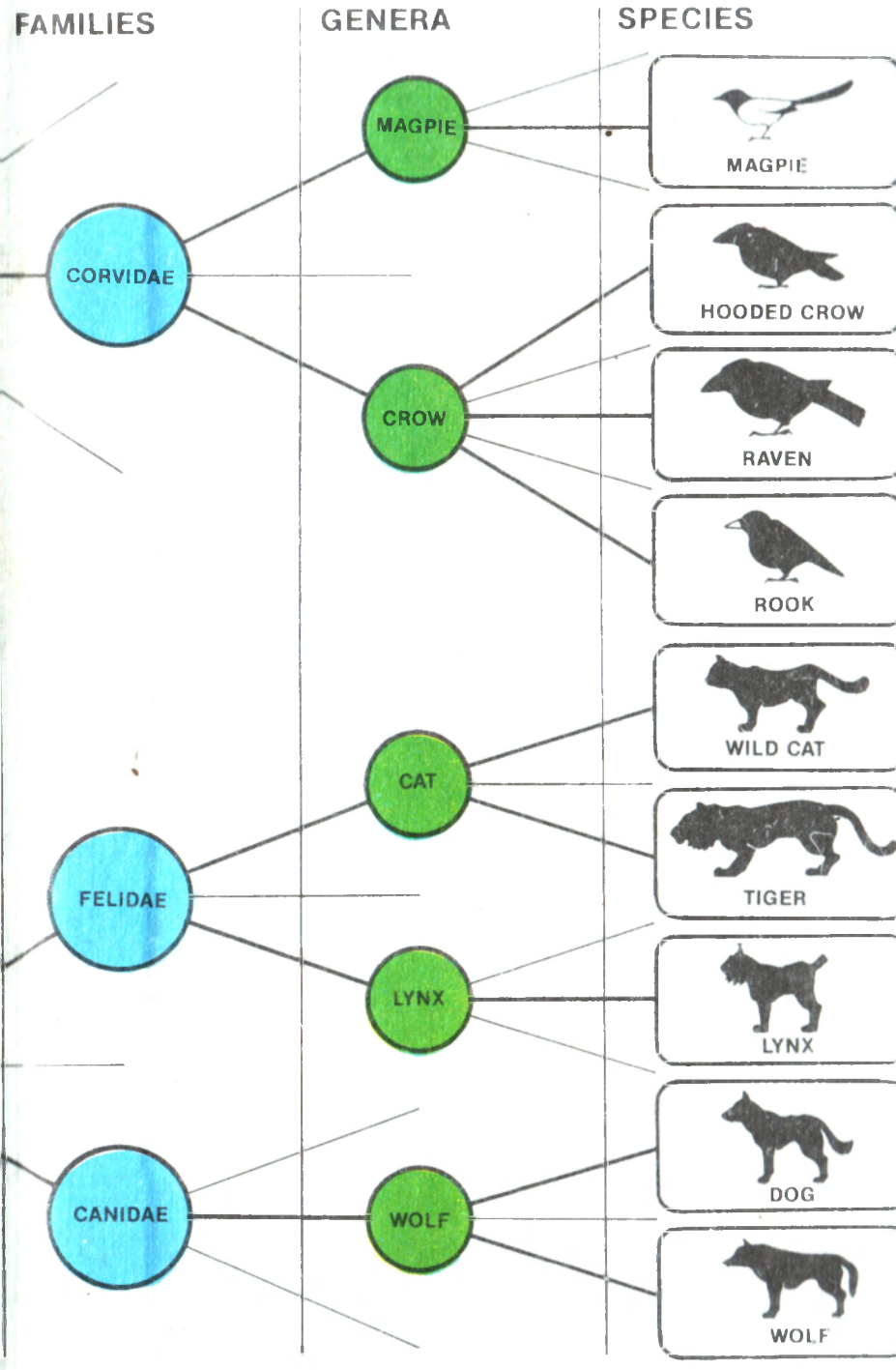
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